IRC:SP:90-2023

GUIDELINES FOR GRADE SEPARATORS AND ELEVATED STRUCTURES

(First Revision)

INDIAN ROADS CONGRESS
2023

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Guidelines for Grade Separators and Elevated Structures

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(as on 25th September, 2022)

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1	President, Indian Roads Congress	(Joshi, C.P.), Secretary (Retd.), PWD Maharashtra and OSD & IE, MSRDCL, Mumbai
2	Director General (Road Development) & Special Secretary to Govt. of India	(Nirmal, S.K.), Ministry of Road Transport and Highways, New Delhi
3	Secretary General, Indian Roads Congress	(Nirmal, S.K.)

1. INTRODUCTION

On account of phenomenal growth of vehicle population on highways and in urban areas, there is an increasing demand to eliminate traffic bottle necks at road intersections by providing grade separated structures for safe passage of pedestrians and vehicles. Such structures segregate traffic moving in different directions at road intersections and are known as flyovers, grade separators, interchanges, elevated structures, viaducts, underpasses/overpasses. The ROB/RUB and LHSs are also grade-separated structures for free passage of highway traffic across Railway lines. Keeping these developments in view, Manual for Grade Separators and Elevated Structures was prepared, which was first published in year 2010. Since then, there have been a lot of changes in types of such structures which include wide deck superstructure carrying 4 or 6-lane carriageway on single pier and constructed with pre-stressed segmental technique and cable supported superstructures, besides environmental and social considerations. A need was felt to revise this Manual incorporating the latest trends in design and construction of such structures. Accordingly, a subcommittee was constituted by B-1 Committee in 2018 comprising: Shri G.L. Verma as convenor and S/ Shri Alok Bhowmick, Shri A.N. Dhodapkar, D.K. Rastogi, D.K. Kanhere, Dr. B.C. Roy and Dr. B.P. Bagish, the draft was deliberated in a number of meeting by the Sub Committee and Main Committee.

The General Design Features (Bridges & Grade Separated Structures Committee (B-1) was reconstituted in 2021. Shri Rajiv Ahuja was later co-opted as member of the sub-committee in 2021. The draft prepared by the sub-committee was discussed in numerous meetings of B-1 Committee and finally approved in its meeting held on 17.01.2022. This was discussed in BSS meeting held on 6th June 2022 and was returned to B-1 Committee for incorporation of certain details. The B-1 Committee considered the suggestion of BSS and complied with all the observations of BSS. The revised document of IRC:SP:90 was approved by the B-1 Committee in its meeting held on 10th September, 2022 the list of Personnel of B-1 Committee is as under:

Sinha, N.K.	.....	Convenor
Kumar, Ashok	.....	Co-Convenor
Goel, Dr. Rajeev	.....	Member-Secretary

Members

Ahluwalia, Ajay	Matsagar, Prof. Vasant
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Director General (Road Development) & Special Secretary to Govt. of India	(Nirmal, S.K.), Ministry of Road Transport & Highways
Secretary General, Indian Roads Congress	Nirmal, S.K.

Keeping in view the provisions of IRC: 5 and other IRC Codes/Manuals/Guidelines and current practices, all Chapters have been updated, specially the Chapters on Underground Structures, Drainage, Illumination, Construction methods and constructability. The title of the document is changed to "Guidelines for Grade Separators and Elevated Structures".

The revised draft was approved by Bridges Specifications & Standards Committee (BSS) in its meeting held on 25th September, 2022 and subsequently, the Executive Committee approved the same in its meeting held on 7th October, 2022 and authorized Secretary General, IRC to place the same before the Council. The modified document was approved by the IRC Council in its Meeting held on 8th October, 2022 at Lucknow (U.P.) for printing.

2. SCOPE

These Guidelines cover various aspects and practices required to be considered in the Planning, Design, Construction and Maintenance of all the forms of Grade separated and Elevated structures including Flyovers, Elevated Roads, Viaducts, ROBs, RUBs, Underpasses, Subways, Pedestrian or Foot Over Bridges and Interchanges both for urban as well as rural or non- urban situations. The requirements and provisions of these Guidelines may be followed wherever applicable, except in cases where local site conditions, bye laws or other regulations require otherwise.

The relevant provisions of the IRC Codes will prevail for these structures also, including definitions of various terms used in this document.

These structures shall be provided only at locations where the volume and intensity of traffic has become excessive of the capacities at level traffic management systems, e.g., signals, railway gates, rotaries and split rotaries etc. or where otherwise required from various other considerations or as a part of future planning. The shape, form and arrangement of the grade separator system shall be decided as per these Guidelines. Reference to grade separators in various Clauses shall be applicable to all grade separated structures and elevated roads *mutatis mutandis*.

3. PLANNING

3.1 Collection of data:

The requirement of a grade separator, its type and configuration at any point of intersection is decided on the basis of classification of the intersecting roads, volume, intensity and type of traffic thereon and need for segregating the same. However, its layout is affected by space constraints, presence of utilities on surface or underground, religious structures, graveyards, orchards, feasibility of regulating traffic during construction, space for storage of construction material, space for manoeuvring of machinery to be used and the like.

Accordingly, relevant data as discussed below are required to be collected, studied and analyzed for deciding the various aspects relating to the planning, layout, design, construction and maintenance of the facility. Reference may also be made to IRC:SP:54 "Project Preparation Manual for Bridges", IRC:SP:19 "Manual for Survey, Investigation and Preparation of Road Project" and IRC:SP:41 "Guidelines for the Design of At-grade Intersections in Rural & Urban areas" for further guidance.

3.2 Index Map/Location Map

A survey of India map of the area (Topo sheet having scale 1cm equal to 500m or 1/50000) showing the proposed location of the grade separator, existing arrangement for movement of traffic, general topography, important towns in the vicinity, schools, religious places etc. is to be obtained and studied. Alternative sites investigated and rejected should also be included therein. The studies can be supplemented with detailed topographical survey and satellite imageries of the area.

3.3 Road Network Plan

Location of the proposed grade separator in the link of the road network of the area is to be ascertained in the first instance. Most road links have different degrees of mobility and accessibility. This aspect has to be considered to ensure smooth movement of traffic at entry and exit of the facility.

3.4 Reconnaissance

Main objective of reconnaissance is to understand the general characteristics of the area. In the case of urban grade separators, the alignment generally follows the existing road. However, the geometry of obligatory span depends upon the geometry of intersecting roads. In the case of open area, the alignment follows the proposed alignment of project road. Some of the details which may not be available from the map study and can be obtained after reconnaissance of the area only are:

i) Permanent structures, archeological structures, religious structures and other obstructions.

ii) Number and type of minor cross drainage structures.

iii) Type of soil along the route and geological features.

iv) Sources of construction materials especially the borrow areas for huge quantities of soil involved in solid embankment and its lead from local enquiry.

v) ROW and type of structures temporary or permanent which may have to be acquired/ removed.

vi) Other activities or developments like metro corridors etc. taking place or planned along or cross the proposed alignment.

vii) Obligatory span and site specific requirements.

viii) In case of urban grade separators, space for storage of construction materials, construction equipment, casting yard and labour accommodation etc.

ix) Feasibility of diversion of traffic during construction.

x) Public utilities in the area and departments controlling them.

xi) Interaction with the concerned departmental officers

xii) Interaction with Public.

xiii) Flood level, if any.

3.5 Master Development Plan of the Area

The Master Development Plan of the area where the grade separator is to be constructed or any other schemes, already planned or being planned, in the vicinity affecting the project should be studied in detail. Its impact, if any, on the planning and detailing of grade separator should be assessed and accounted for.

3.6 Surveys-Site Plan/L-Sections/Cross-Sections

Site Plan: A site plan to a suitable scale shall be prepared. It shall contain the following:

i) The alignment of the existing roads leading to the intersection, location of the proposed crossing and its approaches.

ii) Location of other junctions, in about 500m length of alignment on either side.

iii) The name of the nearest inhabited identifiable locality on either side of the crossing.

iv) Reference to the position (with description and reduced level) of the benchmark to be used as datum.

v) The location of trial pits or borings, each being given an identification number and connected to the datum.

vi) The location of all nallahs, buildings, divided villages, wells, outcrops of rocks (if any), and other possible obstructions to road alignment.

vii) Other connecting main roads of the town and distance from proposed grade separator.

viii) All service lines and utilities must be shown in the plan.

L-Section: L-Section showing ground levels along approved alignment

Cross Sections: Cross sections at 25m intervals may be prepared except in hilly train where these can be taken at 10 m interval.

3.7 Traffic Studies/Surveys

For detailed planning of such facilities which have to be related to the desired level of service along such corridors, it becomes necessary to study, in detail, the present and expected future characteristics of traffic at such locations. The following surveys are required to be carried out for making these studies:

i) Classified Traffic Volume Survey

ii) Turning Movement Count Survey

iii) Pedestrian and Non-Motorized Traffic Survey

iv) Origin and Destination Survey

v) Vehicle Occupancy Survey

vi) Vehicle Speed and Delay Survey

vii) Intersection Volume - Delay Survey with Emphasis on Intersection Queuing and Signal Timing

viii) Road Inventory Survey

ix) Parking Survey

x) Public Transport - Type and Frequency

Traffic Surveys are thus necessary to establish quantitative information on traffic characteristics in terms of overall traffic volume, composition of traffic (public/private/commercial) to estimate the effect on economic/ financial issues, hourly distribution, vehicle occupancy, average speed on road network and delay at Junctions, origins and destination of trips etc. and road characteristics in terms of width of carriageway, available right of way, number of traffic lanes, parking, location of traffic signs, bus stops and lamp poles, width of footpaths, encroachment etc. Analysis of traffic survey data provides valuable inputs for economic and financial analysis of grade separators and thus provides the basis for the justification of grade separators.

If a long section of road is intended to be developed as a fast corridor and even if few junctions of this corridor do not qualify for grade separator on account of minimum PCU, in such a situation the minimum PCU requirement may not come in the way of extending/constructing the flyover over these intersections.

3.7.1 Classified traffic volume survey

Classified traffic volume establishes the magnitude of traffic by different types of vehicles for each hour of the day. Classified Traffic Volume Survey can be carried out manually as well as with the use of video based automatic traffic counters. By utilizing the data obtained from permanent traffic counting stations, 24 hours traffic volume can be worked out for any particular day, month or season to arrive at representative annual average daily traffic (AADT) volume. AADT volumes are used for evaluation of traffic flow with respect to the existing roadway system, measurement of present demand for service by roadway and planning of location of new facilities, new route selection and evaluation of alternative traffic management actions.

In case, there are other intersections within the close vicinity of the intersection under study, it would be a good idea to carry out traffic survey at such locations as well. The peak hour traffic

volumes will be ultimately expressed in terms of equivalent passenger car units (PCU) with the help of equivalency factors.

3.7.2 Turning movement count survey

Turning movement counts at junctions are important for the design of junction, channelization, capacity analysis, traffic signal timing and phasing, turning lanes, parking and turning restrictions. Turning movement counts should be conducted manually and recorded in 15 minutes' interval according to lane movement and by vehicle classification. Alternatively, these can be video based studies. Peak hours (morning and evening) are sufficient for most of the situations. Standard forms are used for data collection for turning movement count survey.

Turning movement surveys at complex intersection:

At complex intersections where the turning movement will be difficult to observe, particularly at rotaries, recording of the registration number plate will be used for collection of the base turning movement data at site during 8 hours dividing into 4 hours each, during the morning and evening peak periods, so as to cover the peak traffic during morning and evening periods.

3.7.3 Pedestrian and Non-Motorized Traffic Survey

For sections carrying heavy traffic, this survey is required for providing safe pedestrian and non-motorized traffic crossing.

3.7.4 Origin and destination survey

Origin-destination surveys are designed to identify the travel pattern and thus allow transport planners to analyze the existing traffic pattern and project future transportation requirements. The computer analysis of the data assists the transport planner to project inter-zonal movements, mode preference and desires of particular population. This study should be made on need basis depending upon complexity of the grade separator

3.7.5 Vehicle occupancy surrey

Vehicle occupancy survey determines the occupancy of passengers in each vehicle. This survey establishes the traffic volume in terms of number of persons by different types of vehicles crossing at a given point. The analysis of vehicle occupancy survey data and junction delay survey data provide valuable inputs in economic analysis of the project.

3.7.6 Vehicle speed and delay survey

Vehicle speed-delay survey is necessary for economic studies such as, cost-benefit analysis for transport facilities. Congestion can be evaluated by means of speed and delay studies. There are several methods which can be used for speed-delay survey.

3.7.7 Intersection volume-delay survey

The Intersection volume delay survey is conducted at any intersection of interest to provide a detailed evaluation of the stopped time delay of either vehicular or pedestrian traffic. For justification of grade separator, intersection volume-delay survey is a must. The information could also be used for the development of proper timing sequences for traffic signals, calculation of delay costs in the economic analysis of highway and traffic improvements and evaluation of geometrics that are critical in intersection design.

Sampling procedure is to be used for the stopped time delay method. This involves the counting of the number of vehicles stopped in the intersection approach at successive intervals. This sampling along with volume count (during the same time observations are made) permits estimating the vehicle stopped time delay.

3.7.8 Road Inventory survey:

Road Inventory Survey provides the details of road and street networks.

The typical information collected from road inventory survey are:

i) Width of Carriageway

ii) Width of Footpath/Cycle tracks

iii) Location of Traffic Signal Posts

iv) Location of Traffic Signs/Advertising Boards

v) Location of Bus Stops/Shelters

vi) Width of Central Divider/Median

vii) Location of Lamp Poles

viii) Location of Manholes

ix) Whether Footpaths/Carriageway Encroached by Hawkers/Stall/Others

x) Schools, Religious Places, Most Preferred Crossings by public

xi) Obstructions due to Existing Utilities/Services

3.7.9 Parking Survey

Parking surveys are required to be carried out to assess the existing parking demand on the roads in the project area and to plan required parking facilities in the surrounding area. The existing demand for onstreet parking facilities will be determined by patrolling the parking area at regular intervals through a period covering both peak and off-peak periods. The length of the road stretch covered by a patrol will be limited by speed of walking and the frequency of patrol. The information collected under this survey will include time, registration number of vehicle and parking duration. From the analysis of the survey data, parking accumulation, parking demand, average duration of parking, etc. will be assessed.

3.7.10 Public Transport - Type and Frequency

Public Transport survey for vehicles moving on the roads in the area is carried out to understand the travel characteristics of public transport users at study location. This would also help in finalizing the desired direction of grade separation. This survey is generally carried out through an interview survey of public transport passengers (Bus, BRT, etc.) on a sample basis. The information to be collected as part of this survey would include frequency of service, number of routes, boarding & alighting at established study location, etc.

3.8 Deciding the Type of Facility

Grade separators essentially segregate traffic in space and depending upon prevailing and expected traffic characteristics, present and proposed development plans for the area, site constraints and environmental constraints & considerations, can be provided in various forms.

The type and classification of the grade separated facilities to be provided at any particular junction or crossing will mainly depend on the following factors:

i) Location attributes – whether in open areas or inhabited or urban areas

ii) Traffic requirements based on the interpretation and analysis of traffic studies made and data collected

iii) Future development plans

iv) Classification and Capacity of intersecting roads and others roads in the areas

v) Level of service required

vi) Local restraints – ROW, underground and above ground utilities and services and environmental issues

vii) Design and construction requirements

The importance of roads and volume of traffic on them will usually decide which one would remain at level and which ones would fly over. Lesser important and lower traffic volume roads should fly over the other unless there are some specific considerations or constraints.

3.8.1 Location attributes

Generally speaking, grade separators in non- urban areas are not confronted with the same degree of site constraints as in the case of grade separators in town/urban areas. It is mainly because of this reason that flyovers/grade separators in non- urban areas tend to take more liberal forms than those in urban areas.

3.8.1.1 Flyovers/Grade Separators in Open/non- urban areas

a) Planning of flyovers/grade separators in open/ non- urban areas is essentially guided by considerations of Level of Service (LoS) that is expected along the designated corridor. The hierarchical pattern of road network along with hierarchical classification of cross roads usually decides the planning of grade separators in such areas.

   Thus, it may be desirable to have a grade separated facility at an intersection between two national highways or between a national highway and a state highway or, NH/SH crossing a village road even though, the level of congestion may not immediately indicate the need for such a facility. This is because of the operational attributes that are associated with traffic operation along National Highways and State Highways which are also designed to NH Standards.

b) An expressway is expected to have only grade separated intersections and as such, provision of such treatments along an expressway becomes an integral part of even the preliminary planning process.

c) Intersections in open areas usually cater largely to long haul through and intercity traffic that may not show any distinct and repetitive peaking characteristics. In order to obtain an accurate estimate of the design year traffic volumes, traffic surveys must be conducted at such locations for 24 hours over seven consecutive days. The survey should be designed in such a manner that category wise traffic counts and turning characteristics of traffic at intersections are adequately covered. The average of seven days of traffic volumes will

give the Average Daily Traffic (ADT) that has to be subsequently corrected for seasonal variations with the help of data available for different seasons from permanent count stations maintained by the state PWD, to arrive at AADT. Traffic surveys done by any reputed organization on national highways using automatic traffic counters and classifiers can also be used wherever feasible. Even if such permanent count station data are not available for the intersection under consideration, a well-judged estimate of the same could be made from data available for nearby count stations that might experience similar fluctuations in traffic volumes as would be expected at the intersection under study. Also, monthly fuel rates data collected from the outlets of nearby areas can be used for arriving at correction factors separately.

In case, Average Annual Daily Traffic (AADT) calculated over 365 days a year is available for the base year such data would also be used for the planning process. The AADT must however, be available with an hourly split up of traffic volumes.

d) For an existing intersection, data on intersection delays must be collected. This information becomes necessary for establishing the viability of the scheme.

Design traffic volume could be defined as that hourly volume of traffic by the design year for which the facility is to be planned. Usually, such a facility is designed for projected traffic at the end of 20 years after construction Determination of design hourly volume requires assessment of peak hourly traffic during the base year and projecting the same to the design year. The design year shall also depend on the concession period for projects under EPC, BOT and the like.

e) Whereas stage construction is possible in the case of roads, it is not so in the case of structures which are being designed for 100 years. As such, while deciding the number of lanes for roads passing over the facility and underneath this aspect has to be kept in view.

f) IRC Manual for two laning /four /six laning indicate the traffic levels for two lanes, four lanes, six lanes, or more lanes . which shall be referred to. Accordingly, overall deck width and its configuration over the structure should be kept such that it should be possible to add more lanes of traffic in future.

Similarly, the length of span over crossing points may be decided keeping in view the future widening of the roads crossing underneath.

3.8.1.2 Flyovers/Grade Separators in urban areas (urban flyovers)

a) Unlike flyovers in open areas, planning of such facilities in urban areas is very frequently guided by space constraints, constraints of underground and overhead services, environmental considerations, aesthetics and urban design norms. One has to also keep in view the city and its corridor layout pattern while planning a flyover in an urban area. Intersections are usually fairly closely spaced in a city and while planning a flyover at an intersection, the impact of the facility on the adjoining intersections must also be suitably assessed. While hierarchical pattern of road network remains an important factor in planning urban flyovers, the traffic characteristics at the intersection remain the most important decisive factor to this effect. Traffic studies thus become a key activity in the context of planning of flyovers in urban areas.

b) Traffic facilities in urban areas are usually planned for catering to peak hour traffic demands keeping in view the future growth of urban area as per Master Plan. It is thus very important to identify the peak hour and the peak hour traffic characteristics at such urban intersections

The decision to provide a flyover shall be based on examination of different alternatives and only after all other avenues of efficient management of traffic through grade treatments are exhausted, such as a properly designed four arm intersection controlled by a traffic rotary or similar intersection controlled by automatic traffic signals. Intersection traffic volumes nearing 10,000 PCU usually result in very inefficient and hazardous traffic conditions and it is at this level of traffic that provision of flyovers generally becomes necessary.

c) Speed and delay survey are considered very important towards justifying provision of flyover at an urban intersection. The data to be collected under this would relate to signal cycle time (if the intersection is signalized), average delay at the intersection and average stream speed over the influence area

Other information to be collected in connection with design of flyovers in urban areas would include information on bus routes and locations of bus stops, hourly volumes of pedestrians crossing the intersection approach arms (at least for 12 hours on an average working day), overhead and underground services and development plans, if any, for the adjacent quadrants

d) As in the case of flyovers in open areas, the design traffic volumes for urban intersections will be the projected peak hourly volume at the end of the design life of the facility (20 years after the construction of the flyover). Determination of design peak hourly volume requires assessment of peak hour traffic during the base year and projecting the same in the design year.

The base year peak hour traffic volume in this case is determined through traffic surveys. However, projecting the traffic to the design peak hour volume is a complex process and has to be attempted following several methods of projection. For such purposes the master plan of the city and its perspective development plan must be referred to in order to find out the expected pace of urban development within the design life of the facility. Traffic generation norms as adopted in the master plan could then be applied to find out the additional traffic demand that would be generated at the Intersection under consideration during its design life. It is possible that in certain cases only projected person trips would be available. In such instances person trips will have to be rationalized in terms of equivalent passenger car units through application of modal split. In certain cities growth factors for peak hour traffic in terms of PCU have already been established. In such cases determination of design peak hour volume becomes considerably easy.

Reference may be made to IRC: 92, Guidelines for the design of interchanges in Urban Areas and IRC:SP:19 “Manual for Survey, Investigation and Preparation of Road Projects” for details on traffic considerations.

3.8.2 Alignment on high skew:

At times to avoid high costs due to large skew of cross road, economy of realigning the cross road may be explored.

3.9 Level of Service (LOS)

3.9.1 Level of Service is a qualitative measure describing operational conditions within a traffic stream and their perception by drivers/passengers. Six levels of service are recognized commonly designated from A to F, with Level of Service A representing the best operating conditions (i.e. free flow) and Level of Service F the worst (i.e. forced or break-down flow) as described in IRC:92.

3.9.2 Capacity standards are fixed normally in relation to the Level of Service adopted for design.

3.10 Alignment and Layout

The alignment and layout of a grade separator is usually determined by the alignments of the intersecting roads or traffic, plan area available and all the geometrical standards and other local restraints or site conditions.

However, wherever possible, the alignment and layout should avoid passing or covering congested areas or locations with too much of above and underground utilities services or while meeting the requirements of the geometrical standards and other requirements of this manual.

3.11 Geometric Configuration

3.11.1 The type of grade separation and interchange, along with its design, is influenced by many factors, such as highway classification, characteristics and composition of traffic, design speed and degree of access control. These controls plus design requirements, economics, terrain and right of-way are of great importance in planning these facilities with adequate capacity to safely accommodate the traffic demands.

3.11.2 Simple grade separators are provided when the high volume traffic is to be segregated through elevated structure. The rest of the traffic still passes at the level roads.

3.11.3 Interchange, a system of interconnecting roadways in conjunction with one or more roadways or highways on different levels, two levels or multilevel, are provided when several directional traffic is to be segregated from one another and all traffic is to be made signal free.

3.11.4 Justification for grade separated interchanges : Interchanges, in general, are expensive to construct and a major factor influencing the cost is the type of arrangement made for the various traffic movement. The arrangement may range from separating only one traffic movement from other to the complete separation of each traffic movement from every other movement, so that only merging and diverging movements remain. Similarly, the vehicle operating cost will vary depending on the type of ramp arrangement, from direct conflict-free connections to indirect connections involving extra travel distance. However, the following points may be helpful in guiding the choice of an interchange at the preliminary planning stage:

i) Interchange will be necessary at all major crossings of a highway which is to be developed to completely access controlled standard. Similarly, Interchanges will be required at all major crossings on highways developed to expressway standards.

ii) An Interchange may be justified at the crossing of a major arterial road with another road of any category.

iii) An interchange may be justified when an at-grade intersection fails to handle the volume of traffic resulting in serious congestion and frequent choking of the intersection. This situation may arise when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour.

iv) High and disproportionate rate of fatal and major accidents at an Intersection not found to respond to other traffic control or improvement measure may warrant an interchange

v) In some situations, the topography is such that interchanges are the only type that can be constructed economically.

vi) The requirement of interchange may also be justified from the existing constraints of the junctions other than traffic volume, like parking, market, important and religious structures buildings with frequent crowding.

3.11.5 Geometric configurations (common type) : The common geometric configurations of interchanges are the trumpet, diamond, cloverleaf, rotary and directional as shown in the **Fig. 3.1 & Fig. 3.2** given below. Reference may be made to IRC:92 for detailed description of various types of interchanges. Within each type of interchange, there can be several variations such as split diamond, partial cloverleaf etc. Depending on the ramp arrangements. The salient operational conditions for each of these interchanges are given below.

i) Trumpet interchange

A trumpet interchange is a 3-leg interchange. This is the simplest interchange form adaptable to "T" or "Y" intersections. Of the two right turning movements, one is negotiated by a loop while the other is negotiated by a semi-direct connection. Diagonal ramps are provided for left turning movements. Several variations of the design are possible depending on the type of connection provided. The type of connection provided for the right turning movements should be based on traffic volumes. The ramps catering to heavy traffic volumes should preferably be provided with direct connections

ii) Diamond interchange

Atypical diamond interchange is the simplest of 4-leg interchange designs and is particularly adaptable for major-minor highway intersections. The ramps which provide for one-way movement are usually elongated along the major highway and may be curved or parallel to the major highway. The ramp terminals on the minor road are at grade intersections providing for right and left turning movements. The at grade intersections may be controlled by signals if warranted by traffic volumes or in the absence of adequate sight distance

iii) Cloverleaf interchange

The design of a typical cloverleaf interchange consists of one loop ramp for right turning traffic and one outer connection for left turning traffic in each quadrant. Vehicles desiring to turn right are required to turn left through about 270 degrees before attaining the desired direction

iv) Rotary interchange

This type of design is particularly useful where a number of roads intersect at the interchange and in locations where sufficient land is available. It requires the construction of two bridges and

generally necessitates more land than for a diamond layout. The main highway goes over or under the rotary intersection and turning movements are accommodated by the diagonal ramps.

The capacity of a rotary interchange is similar to that of at grade rotary. High speed operations cannot be maintained on the minor road because of the usually short weaving distances. It can, however, operate satisfactorily at low speeds. Also this type of design entails only a little additional travel distance for interchanging traffic which is a significant advantage when slow moving traffic is present.

v) Directional interchange

Directional interchanges have ramps for right turning traffic which follow the natural direction of movement. This type of design requires more than one structure, or a 3-level structure. Though operationally more efficient than other designs, these generally turn out to be very expensive.

vi) Land requirement

Approximate land requirements of interchanges as per IRC:92 are as given below (**Table 3.1**):

Table 3.1 Land Requirements for Interchanges

Sl. No.	Category	Approximate total land in hectares
i)	Trumpet interchange	4.4
ii)	Diamond interchange	2.8
iii)	Full cloverleaf	7.3
v)	Bridged Rotary	18.0

3.11.6 Desirable normal & acceptable standard

Planning of grade separators and elevated structures in urban areas requires special consideration for fitting them within the constraints of the urban scenario. Very often Right-of-Way (ROW) is restricted in developed urban situations both in the horizontal and vertical direction on both sides of ROW leading to curves which are beyond acceptable criteria of design codes. The vertical profiles are constrained due to the presence of traffic junctions very closely spaced to one another leading to gradients steeper than those permitted by prevalent design codes.

In such situations, especially in urban areas with sanctioned development plans, specific conditions may be required for the various geometric parameters and are summarized as being "Desirable", "Normal" and "Acceptable"

Desirable	which in the normal course must be executed on any part of the structures.
Normal	which is less than desirable parameter and which can be used in case it is not possible to achieve desirable parameter.
Acceptable	which can be used in exceptional circumstances for which competent authority's approval may be sought

Where an ideal situation exists, the target should be to achieve desirable parameter. However, if it is not possible, then it should be permissible to adopt normal parameter. But in urban areas, in a few cases as an exception, it might be necessary to allow further relaxations on acceptable

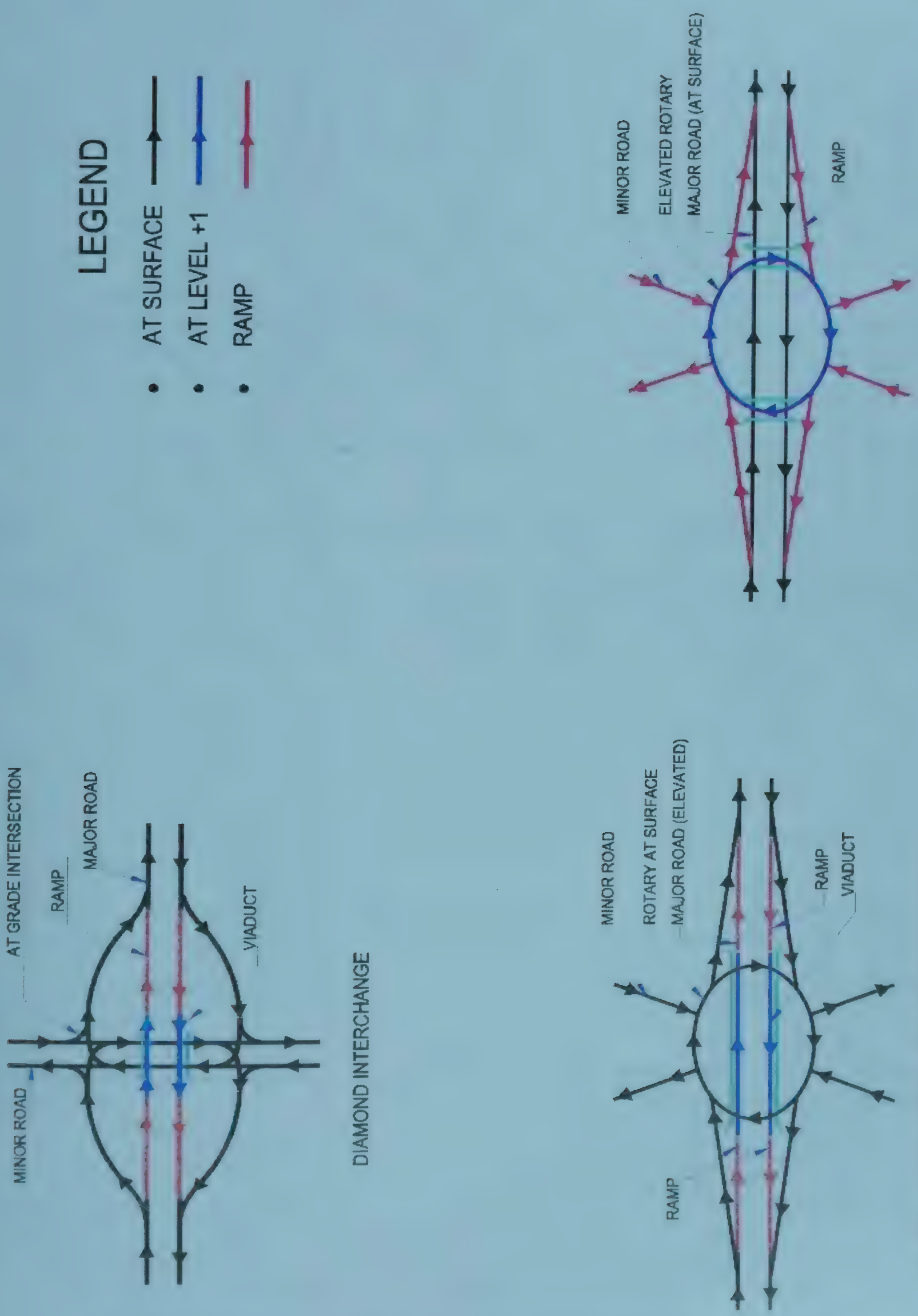

Fig. 3.1 Different Types of Grade Separated Arrangements

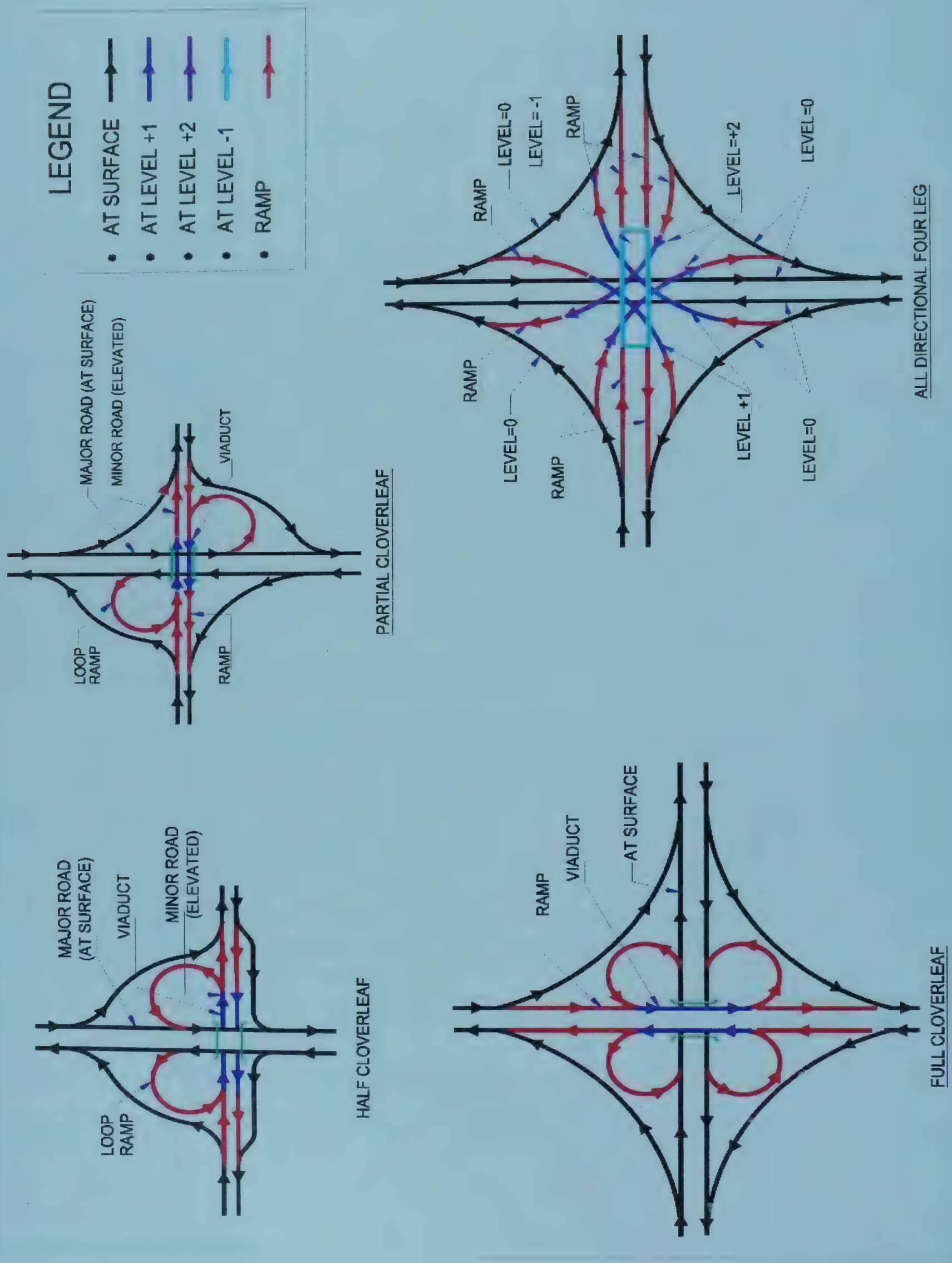

Fig. 3.2 Different Types of Grade Separated Arrangements

standards. This has been classified under acceptable norms. It is suggested that whenever the "acceptable norms" need to be used, the Engineer will record the reasons for adopting these standards. Whenever junctions are closely spaced and the junctions are on narrow roads and therefore cannot allow tall truck traffic or bus traffic, it can be considered to reduce the clearance at these junctions after analyzing all the relevant factors. Any vehicle requiring more than this vertical clearance can go to next ideal junction where higher clearance is available.

While considering the acceptable limits, it should be carefully examined and ensured that this will not in any manner affect the proper functioning, serviceability and safety of the interchange. This should not create any possibilities for obstruction to smooth flow of traffic and causing traffic jams.

Geometric standards and other requirements can be fixed as per the recommendations in IRC:86 "Geometric Design Standards for Urban Roads in Plains". For rural areas,IRC:73 "Geometric Design Standards for Rural (Non-Urban) Highways" can be referred.

3.12 Study of Data regarding Utility Services, Structures and Trees Falling in Project Area

3.12.1 Study and mapping of utility services, structures and encroachments and trees

The study and mapping of all the overhead and underground utility services e.g telephone cables, water supply and sewerage pipes, gas pipes etc. or structures, encroachments falling in the project area is very important step in the planning, design, construction and maintenance of grade separators.

The knowledge of the nature, correct location, alignment, size, depth or height and the importance of the service is essential so that the requirements of shifting, relocation or its effect on design and construction are assessed and adequate steps taken to make the area encumbrance or obstruction free before the commencement of construction, so that the work is not interrupted again and again on this account causing uncontrollable delays and lots of inconvenience and discomfort to the traffic in that area.

The data about all this has to be collected from the records of the concerned organizations or agencies and by doing Geo-Physical and Topographical surveys and investigations at site.

Generally, coordination with any or all the following authorities may be required based upon the project requirements:

• Revenue Department	• Acquisition of land/buildings or removal of encroachments, removal of encroachment
• Police	• Traffic Control
• Municipal Corporation	• Water pipe lines, sewer lines, Master Plan
• Authorities like Public Works Department (PWD), Public Health Engineering Department (PHED), Water Boards & Development Authorities or Improvement Trusts	• Storm Water Drains, Roads, Land, ROW, any proposal for widening of roads
• Telecommunication	• Telephone lines
• Railways	• In case of ROB / RUB
• Transport Departments	• Traffic data
• Town Planning	• To keep in view the Master Plan/ Development Plan of the area while deciding layout.
• Electricity Board	• For transmission lines, electric lines, street lights,
• Gas Authorities	• For Gas Pipe lines
• Urban Arts Commission etc.	• For urban planning and aesthetic considerations
• Environment Control Agencies	• For environmental, rehabilitation and pollution control clearances
• Fire and Safety Organizations	• For safety clearances
• NGOs	• For R & R issues
• Forest Deptt or Concerned Central Govt. Agencies	• For tree cutting etc.
• Airport Authority	• If flyover lies in the approach path of aircrafts
• ASI / Heritage Deptt etc.	• For clearance if structure affecting monuments or is in heritage zones
• Irrigation Department	• For canal crossing, Tanks, Tube Well, Ghats, etc.
Other organizations as per the requirement of the project (which may be affected / connected directly or indirectly)	

3.12.2 Plan, program and cost estimate for removal, shifting or relocation of utility services, structures and removal of encroachments and cutting of trees

A detailed plan of these existing services and structures should be made and then removal, shifting or relocation plan and program concerning all the departments be made separately in consultation with them.

Further requirement of utilities may also be projected in the plan. Similarly, Plan and program for removal of encroachment be made and cost assessed.

The number of trees falling in the project area which will be required to be cut should be counted and the plan to cut or transplant them is to be prepared and necessary permissions should be taken in time. The work, many times, suffers badly on this account as the clearances required from Forest Department and Govt. of India take lot of time. The effort should, however be made to remove as minimum number of trees as possible.

As many Government organizations and other agencies are responsible for the running and maintenance of the different utility services or structures, lot of coordination work and efforts are required in making and implementing this shifting or relocation plan.

This also involves the expenditure incurred on this activity which is to be paid to them and provision has to be made in the cost estimate of the project. Many a times, various organizations make the estimates for this cost, as related to them, which has got to be sanctioned as per their prescribed procedure.

All this and actual shifting, removal or relocation takes very long time and constant pursuance is required. Proper provision of the time required for this work must be kept in mind while setting out the time for completion of construction.

3.12.3 Utility Planning Manager/Co-ordinator

Considering the importance of the activity of removal, shifting/relocation of underground and above ground utility services and structures falling in project area, it is appropriate that one person is made responsible for making adequate studies and prepare the plan and program along with the assessment of costs involved and coordinate and monitor the progress of its implementation . He may be designated separately as Utility Planning Manager or Co-ordinator.

3.12.4 Phasing out this activity

It is also appropriate that the work of these utilities shifting etc. is got carried out separately before taking the construction of the grade separator so that the uncertainty on this account is removed and there is no adverse effect on the progress of the project as per the work program.

3.12.5 Restrictions and limitations in planning, design and construction

Many times, it is not possible to remove, shift or relocate any services, encroachments or structures falling in the project area for various reasons.

Such situations should be identified at the time of the above studies and a note about the same be sent to the Designer/Contractor so that its effect is adequately considered and provided for in the layout, design and methodology of construction at the initial stage itself.

Sometimes, various old, abandoned, buried or unused underground services or structures are not located from the records or site surveys and investigations and their existence is known at the time of actual construction operations of the foundations. In such cases also, its effect is to be considered by the designer and the layout, design and construction techniques are accordingly modified or revised.

3.13 Plan and Program of Acquisition of Land and Structures

It is usually not possible to plan a grade separating facility, especially in urban situations, within the land available in ROW limits of the concerned department. As such, assessment of land to be acquired and estimation of costs has to be made as per the final layout of the grade separator. The acquisition of land will also include the land required for making the diversion roads, if any.

The detailed plan of acquisition of the land and the structures has to be made and cost of acquisition worked out and added to the cost of the project. The necessary procedure to acquire the land should be initiated and land acquired before start of work.

It is necessary to provide access to various utilities which are required to be maintained frequently.

3.14 Geotechnical Data and Geophysical Investigation

3.14.1 Geotechnical Investigation

Geotechnical data is required for the design of foundation in the same manner as it is required for any bridge structure and as given in IRC:78 and MORT&H Specifications. Ideally, one bore hole shall be done at the location of each and every foundation location. The depth of the bore shall be as per the provisions of IRC:78 and MORT&H Specifications for different types of foundations.

The study and analysis of the sub-soil data will be required for deciding the type of foundations to be adopted for the structural part of the grade separator and if any ground improvement is necessary for the approach embankment portion.

Detailed sub-soil exploration for the approach embankment portion of the interchange should also be done for proper design of embankment and pavement to meet the requirements IRC:75 "Guidelines for Design of High Embankments" and IRC:37 “Guidelines for Design of Flexible Pavements".

3.14.2 Geophysical Investigation

Wherever required, Geophysical Investigation should be carried out for determining:

a) Subsurface characterisation for depth of bed rock, type of rock, layers and fractures in rock, water table, weak zones and expansive clays etc.

b) Location of buried utilities for construction of flyovers and grade separators in urban areas

c) Indicative engineering properties of substrata

d) Borehole locations and reliable information about the nature and variability of the subsurface

e) Subsurface information in environmentally sensitive areas and where drilling is not feasible

f) Shear wave velocity required for site specific seismic studies

Guidance may be taken from IRC:123 “Guidelines on Geophysical Investigation for Bridges” which describes major advantages of geophysical investigation and provides basic knowledge of geophysical methods during geotechnical investigation, construction, and maintenance of bridges.

3.15 Climatic Data

Climatic data i.e usual annual temperature range, probable wind velocity, rainfall characteristics indicating period of rainy seasons, relative humidity and salinity or presence of harmful chemicals in the atmosphere or water, subsoil water table, susceptibility to severe storms, cyclones, etc. is to be collected for deciding the various parameters of designs, durability considerations and drainage requirements.

3.16 Requirements of Aesthetics

The grade separators are very important structures and are integral part of the locations. Guidelines given in IRC:5 may be generally followed. As such the structural forms, lines and finishes of these structures should be pleasing and beautiful. The layouts and elevations should be planned such that these effects are created and they look sleek and fitting into the surroundings rather than looking Imposing and ugly.

The dimensions of various components are so proportioned that the design and appearance looks balanced and streamlined.

Pre-cast facia panels or special patterns may be used as part of superstructure to give the desired effect, if the original lines and shape fail to do so.

Landscaping of the entire area with proper and attractive plantation may add to this aspect. Various surface finishes for each element may be used to enhance the aesthetic appeal.

The concrete surfaces achieved after removal of shuttering should not be allowed to be plastered in any manner. To avoid bad surfaces, use of only high quality forms should be allowed. Rubbing unevenness by carborundum stones may be done to remove oil spots of forms & make the surface fresh & new.

A large number of special architectural textures and finishes using concrete and special forms of shuttering are possible

The surface finishes should be selected in such a manner that there is no possibility of being marred by pasting of advertisements or slogan writing.

Sometimes, painting with suitable paints may be resorted to and the same should be maintained periodically.

In moderate exposure conditions cement based paints or lime wash may be used.

In marine or other aggressive environments, special surface paints based on epoxy or polyurethane formulations can be used to help in reducing penetration of harmful chlorides or travel of moisture from surface to inside. The painting scheme should be aesthetically appealing.

The choice should fall on simple patterns, or relief and use of colour scheme giving effect of spaciousness

The shape and forms of Railings, view cutters, noise barriers or Posts and Pillars etc. should be matched with the local architecture motifs and reliefs.

Proper design of signages, illumination and road surface markings can also boost the aesthetic effects

In case of underpasses glazed or terra-cotta tiles can be used.

3.17 Traffic Diversion and Regulation Plan

The traffic diversion and Regulation Plan during different construction stages should be decided at the planning stage for the grade separator. The relevant IRC codes may be referred for requirements of traffic diversion.

The diversion routes should be so planned that the disturbance to traffic on that route is minimum and for a limited period. The quality, specifications and the geometries for the diversion roads be kept reasonably good to meet the requirement of traffic plying there and of minimum maintenance

The construction stages of different activities can many a times be so planned that the roads i.e., service roads etc. which are to be constructed as part of the project are phased and used to suit the requirements of traffic diversion.

If the diversion is planned on new land, it may require its temporary or permanent acquisition for which necessary timely action will have to be taken and cost of acquisition will have to be added to the cost of the project

3.18 Planning for Construction Corridor and Land Required for Construction Activities

The requirements of construction space have to be identified so that its availability could be ensured. This should consider the land and space required for creating a construction corridor for different activities at different times, in plan and elevation, without causing disturbance or obstruction to the existing traffic, for making the site office, Laboratory, storage and movement of machine and material, space for Batching plants, Hot mix plants, Casting Yards and accommodation for labour etc. Though this may have to be done by the construction agency but identification of the requirements and matching them with the available space and land is necessary at planning stage so that appropriate designs and construction methodology are conceived.

3.19 Environmental Issues

This is also an important aspect. All the environmental issues related to the implementation of the project should be studied and analyzed so that the required clearances may be obtained in time and Environment Management and Mitigation Plan could be made without causing problems to the project as detailed in Chapter-.

Many issues involved in this may be critical in deciding the type and location of different plants. In selection of materials and method of construction to avoid air, soil and water pollution and conservation of environment and saving of energy.

3.20 Drainage

Effective drainage shall be ensured by providing drainage spouts connected with horizontal and vertical pipe system such that the water from the structure does not fall on the roads, does not stagnate over the roads or at entry and exit points of the structure and is discharged into the overall draining system devised for the project area as per the provisions in IRC:SP: 50 & IRC:SP:42 and in subsequent Chapter 11 of this guideline. Suitable pumping system with automatic sensors should be provided for underpasses, subway, RUB etc.

3.21 Pedestrian Facilities

Suitable and adequate pedestrian facilities have to be provided at all arms of the grade separator to facilitate safe movement and passage of pedestrian traffic crossing them. If no facilities are provided they tend to cross the roads at these locations at anyplace risking their safety and creating chaotic conditions for the vehicular traffic leading into delays and serious accidents. The volume of pedestrian traffic and the locations where the facilities for crossing the roads are to be provided should be identified at the planning and design stage

The type of facility, whether a signal crossing, pedestrian subway or foot over bridge, should be decided based on the functional requirements, traffic volume on the roads, traffic volume of the pedestrians, feasibility of construction and aesthetics etc. IRC:103 may be referred to for this purpose.

3.22 Services to be carried on the Elevated Structures:

Wherever required, the structure of the bridge shall cater for traction wire supports, poles or pillars for lights, trenches or other suitable ducts for electric supply. Grade Separators are normally not expected to carry other utilities. However, in urban areas and particularly those involving crossing of railway lines (ROBs) other services and utilities such as telephone / power lines, water mains and gas line may need to be carried on the bridge structure. While planning, attention should be paid to their arrangement, location, accessibility and prevention of structural damage to the bridge

3.23 Interaction with Local Public

Before planning any facility views of the local public be also obtained and concerns raised by them be addressed to the extent possible keeping in view the financial constraints.

3.24 Guidelines on Provision of Vehicular Underpass/Flyovers in semi -urban areas

In semi – urban areas, following provisions may be kept in view for providing a better facility to the road users, safer roads and to cater to the requirements of future traffic on the cross roads:

i) Life of these structures is 60 years. The traffic projections for the next 15-20 years should be kept in mind while designing VUPs/ Flyovers, particularly in semi-urban areas where expansion of town is imminent.

ii) At all locations of built-up areas and in semi-urban areas where high traffic growth is projected in the time to come, a minimum of 3 spans for vehicular underpass should be provided with a minimum lateral clearance of 30 m for the main span & 15 m for the viaduct spans on either side.

iii) At locations other than (ii) above, single span underpass shall be provided with minimum lateral clearance of 12-15 m which includes 1.5-2.5 m raised footpath for pedestrians on either side.

iv) At such single span underpasses, suitable traffic calming measures viz. road signs, markings, etc. shall be installed as per IRC:99 provisions. Further, the section of cross road below the main span of all VUPs and the entry service road in either direction shall be provided with paver block/ cut stone pavement for a distance of 60-90 m from the junction for enforcing speed restrictions. The indicative arrangement is shown in **Fig. 3.3** and **Fig. 3.4**.

v) For providing better line of sight, the visibility between the traffic plying on the cross road and the traffic on slip road shall be improved at the junction of RE wall and the structure by adopting suitable measures such as chamfering/ bevelling, tapering, provision of gap slab etc., as indicated in the **Fig. 3.3** and **Fig. 3.4** and the structure be designed accordingly. Further, the lateral clearance between the outer face of the structure & the inner edge of the service/ slip road on either side shall be maintained between 1.5m to 4.5m at the point of approaching the crossroad, depending on the ROW available, as indicated in the **Fig. 3.3** & **Fig. 3.4.**

vi) In order to avoid crisscrossing of pedestrians on divided highways especially at start & end of approaches to the structures, New Jersey Type Concrete Crash Barriers (NJB) or Steel Railing with a height of 1.2m (to make it unclimbable) shall be provided for a minimum length of 50m so as to discourage such crisscrossing and avoid accidents. NJB may be provided where cutting of railing/ theft/ vandalism is expected, otherwise steel railing may be provided for better aesthetics and to avoid blinding effect. If pedestrian cross traffic is high at such locations, even FOBs shall be planned.

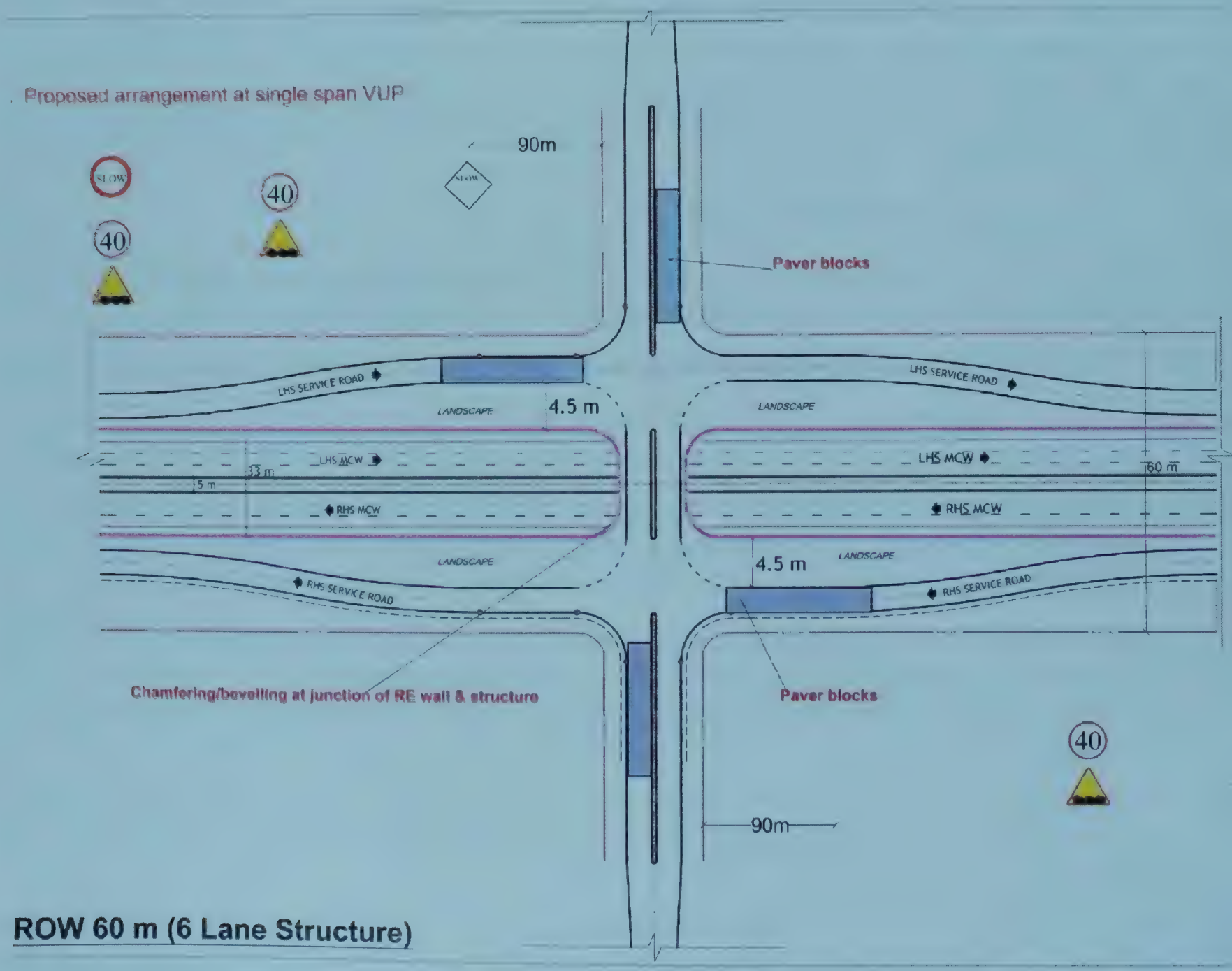

Fig. 3.3 Typical Arrangement at Junction of Cross Road and Service Roads at 6 Lane Structure Location

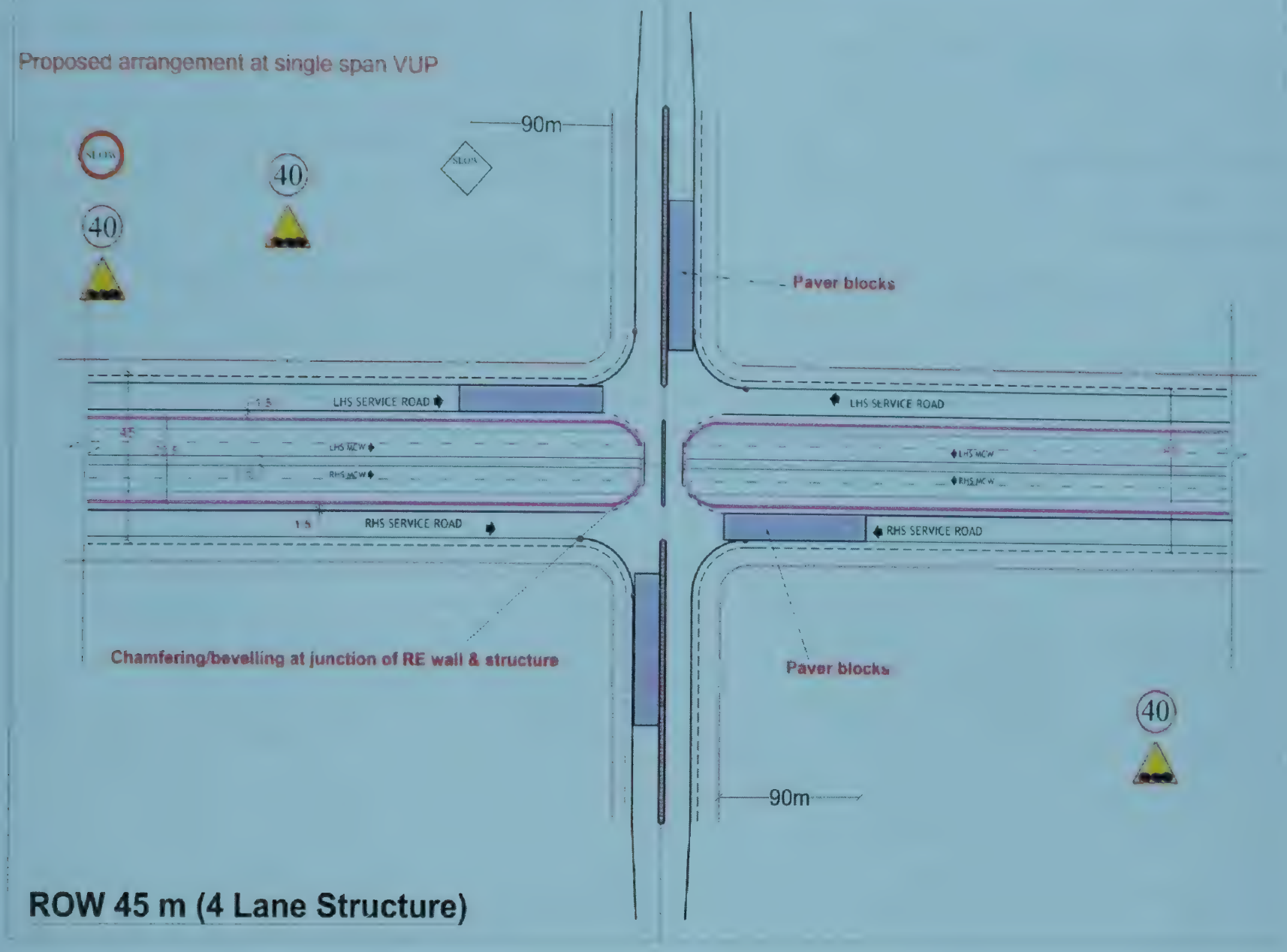

Fig. 3.4 Typical Arrangement at Junction of Cross Road and Service Roads at 4 Lane Structure Location

3.25 Grade Separated Road along Existing Alignment

In view of non-availability of encumbrance, free site for constructing a bypass in some cases, construction of elevated bypasses along existing alignment through the towns and cities, but with improved geometrics, can be an option, which shall be considered at feasibility stage recommended in MORT&H Circular No. RW/NH-3304/35/2012/S&R (R) dated 31st October 2012.

4. GENERAL FEATURES & GEOMETRIC STANDARDS

The objective of geometric design is to provide maximum efficiency in traffic operations and maximum safety at reasonable cost.

General Features and Geometric Standards shall be based on relevant IRC Codes. The list of such codes is mentioned below and should be followed as per the location of the structures and hierarchy of the road project.

Table 4.1 List of Codes for General Features and Geometric Design

Code/Manual	Title
IRC:5:	Standard Specifications and Code of Practice for Road Bridges Section - I General Features of Design
IRC:SP:73	Manual of Specifications and Standards for Two laning of Highways with Paved shoulder
IRC:SP:84	Manual of Specifications and Standards for Four Laning of Highways
IRC:SP:87	Manual of Specifications and Standards for Six Laning of Highways
IRC:SP:99	Manual of Specifications and Standards for Expressways
IRC:73	Geometric Design Standards for Rural (Non-Urban) Highways
IRC:86	Geometric Design Standards for Urban Roads and Streets
IRC:SP:128	Urban Roads Manual
IRC:SP:48	Hill Roads Manual
IRC:52	Guidelines for the Alignment Survey and Geometric Design of Hill Roads
IRC:92	Guidelines for the Design of Interchanges in Urban Areas

4.1 Carriageway Width

i) The carriageway width shall be provided as per the provisions of IRC Codes for the traffic requirements as determined by traffic census and studies. The carriageway width on the elevated structure shall be kept same plus kerb shyness as on the approaching roads on either side and the widths shall not be reduced abruptly. Suitable merging/diverging lanes shall be provided in highway system, so that traffic entering or taking off do not conflict the main traffic of the elevated structure. Suitable requirements of taper lengths shall be provided as per relevant IRC Codes/publications

ii) The carriageway width on the connecting one-way loops or curved structures shall be not less than equal to 2- lanes.

iii) Extra widths shall be provided on curves as per the relevant IRC Codes.

iv) For long structures refuge should be provided for any breakdown vehicle at about 200m centres.

4.2 Foot Path

For safety of pedestrians, footpaths, wherever necessary, should be provided alongside the carriageway. They should preferably be provided on either side of the carriageway and should conform to relevant IRC codes/Manuals. To attract full use by pedestrians, the walking surface

should be properly surfaced or paved with all safety provisions of the users from the main traffic. The surface of the footpaths should be sloped and detailed adequately as per relevant IRC codes/ publications to drain off the rain water to avoid any accumulation of water on footpaths. Those parts of the footpath immediately adjoining buildings, fences, trees and other obstructions, which will not be available for free movement of pedestrians should be disregarded while calculating widths required. Wherever footpaths are provided, minimum width of footpath shall be 1.5m and shall be increased suitably for urban and populated areas having large concentration of pedestrian traffic in accordance with IRC:86 'Geometric Design Standards for Urban Roads and Streets' and IRC:SP:128 'Urban Roads Manual'. Footpaths on Grade separators may be omitted where surface levels roads (Service/slip roads) with footpaths are provided alongside the grade separators. Footpaths on ROBs shall be provided as per criteria given by Railways.

4.3 Kerb

The footpath/median Kerbs shall be provided on the deck as per the details given in IRC:5 and other relevant IRC Codes and also as per site requirements.

4.4 Railings, Parapet and Crash Barriers

4.4.1 Railings or parapets shall be provided for the protection of pedestrians or cyclists as per IRC:5 code. Suitably designed crash barriers shall be provided on both sides of the carriageway as per IRC:5. Apart from its structural strength, considerations shall be given primarily to the architectural features of the railing or parapet to obtain proper proportioning of its various elements to harmonize with the structure as a whole. Consideration shall also be given to avoid, as far as is possible obstruction of the view from the passing vehicles.

4.4.2 High containment crash barrier shall be provided for ROBs across railway lines, complex interchanges and high risk locations as per IRC:5.

4.5 Lamp Post

The height and spacing of the lamp post shall be decided to achieve the desired level of illumination on the carriageway as determined by the provisions indicated in the subsequent Chapter 12 of this guideline.

4.6 Bearings and Expansion Joints

4.6.1 The type of bearings and expansion joints to be provided should be carefully decided at the time of design, so that it remains functional and in place throughout the life of the structure, requiring minimum maintenance. These should be designed and detailed as per relevant IRC Codes.

4.6.2 Possibility of lifting and resetting the bearings for alignment etc. in future should be taken into consideration while designing the bearing and the supporting structure. Locations of bearings, lifting jacks and seismic devices should be decided accurately at the time of design of related components.

4.6.3 Improper selection of type of expansion joints and bearings results in its becoming unserviceable soon causing problems to the traffic as well as to the structure.

4.6.4 To improve the riding quality of road, the number of expansion/contraction joints should be kept to a minimum.

4.6.5 Expansion joints provided should be very sturdy and fixed properly under the expert guidance of the supplier to avoid their frequent repairs and dislodgement. The type that may require minimum maintenance should be preferred.

4.7 Wearing Coat

4.7.1 The wearing coat shall be provided over the deck to resist traffic wear and to provide a smooth riding surface. This can be either of cement concrete or bituminous. The type of the wearing coat shall be decided at the time of design. MORT&H Specifications for Road and Bridge Works may be referred to for details.

4.7.2 Extra loads on account of increased thickness because of renewals and repair should be considered in design, as per IRC:6. But the wearing course should preferably be laid after scarifying/removing the old wearing course to limit the wearing coat loading as considered in design.

4.7.3 Structures where possibility of accumulation of rain water is high like subway, underpasses etc. and also where approach roads are rigid concrete pavements, cement concrete wearing course should be preferred. Water proofing course should be provided on deck slab to prevent ingress of water.

4.8 Safety Barriers /Protective Measures for Piers & Abutments

To prevent vehicles from accidental collisions with abutments or piers, safety barriers such as metal beam or concrete crash barriers of suitable height should be provided. These should be of robust design to effectively resist uprooting and loosening of the support in the event of a collision. The ends of the safety barriers should be turned away from the line of approaching traffic so as to deflect runaway vehicles which may otherwise hit the structure. It is also essential that safety barriers are provided on both sides of the central piers or columns. Reference may be made to IRC:5 and IRC:SP:73/SP:84/SP:87 for detailed guidelines on providing protective measures around piers and abutments which are likely to be subjected to vehicle collision.

4.9 Design Speed

4.9.1 Design speed is related to the function of a road. Keeping in view the type of function expected of each class of the road system, the design speeds given in the following Tables (**Tables 4.2 to 4.5**) are recommended for adoption:

Table 4.2 Design Speeds National and State Highways in Non-Urban areas (IRC:SP:73/SP:84/SP:87)

Nature of Terrain	Cross Slope of Ground	Design Speed (km/h)	
		Ruling	Minimum
Plain and Rolling	Up to 25%	100	80
Mountainous and Steep	More than 25%	60	40

In Urban areas, Design Speeds shall be as given in the following **(Table 4.3)**.

Table 4.3 Design Speeds (km/h)
(IRC:86, Table 3.1 and IRC:SP:128 Table 3.1)

S. No.	Class of Urban Road	Type of Terrain		
		Plain	Rolling	Mountainous and Steep
1	Urban Expressway	80	70	60
2	Arterial Road	60	50	40
3	Sub Arterial Road	60	50	40
4	Collector Street	40	40	30
5	Local Street	30	30	20

For expressways, higher design speeds are adopted as given below **(Table 4.4)**:

Table 4.4 Design Speeds on Expressways
(Table 2.1, IRC:SP:99)

Nature of Terrain	Cross Slope of Ground	Design Speed (km/hr)
Plain	Less than 10%	120
Rolling	Between 10 and 25%	100

Design speeds on Hill Roads are much less and are given below **(Table 4.5)**.

Table 4.5 Design Speeds on Hill Roads
(Table 6.4, IRC:52)

S. No.	Road Classification	Mountainous Terrain		Steep Terrain	
		Ruling	Min	Ruling	Min
1	National and State Highways	50	40	40	30
2	Major District Roads	40	30	30	20
3	Other District Roads	30	25	25	20
4	Village Roads	25	20	25	20

4.9.2 A lower or higher value compared to that given above may be adopted depending on the presence of physical controls, roadside development and other related factors.

4.9.3 A lower design speed may be adopted in the central business area or areas with extremely heavy roadside development. On the other hand, in suburban areas, a higher value may be more appropriate.

4.9.4 For divided highways, running speeds of vehicles are generally higher and, therefore, in such cases a higher value may be adopted. It should, however, be kept in view that sudden change in design speed along any road should be avoided. Change where necessary, should be made in stages in steps of 10 km/hr at a time.

4.10 Space Standards

4.10.1 The space standards, also commonly referred as land width or right-of-way(ROW), recommended for the various categories of roads are given below (**Table 4.6**):

Table 4.6 Space Standards for Various Category of Highways

Category of Road	Land Width (ROW)
2-Lane Highway as per IRC:SP:73	30m for existing and 45-60 m for Bypasses
4-lane Highway as per IRC: SP:84	60 m minimum
6-Lane Highway as per IRC: SP:87	60 m minimum
Expressways as per IRC: SP:99	90-120 m for Rural Section and 120 m in semi-urban areas

In case of elevated roads, the width of ROW may be reduced as per site conditions and availability of land.

In Urban areas, recommended land widths, based on IRC:86 are given below **(Table 4.7)**:

Table 4.7 Recommended Space Standards for Roads in Urban Area

Sr. No.	Type of Urban Road/Street	Land Width (m) and Type of Terrain		
		Plain	Rolling	Hilly
1	Urban Expressway	45-75	35-60	30-50
2	Arterial Road	45-60	35-50	25-40
3	Sub Arterial Road	30-45	25-35	20-30
4	Collector Street	15-30	12-25	12-20
5	Local Street	10-15	10-15	10-15

For Hill Roads, desirable land width or ROW is given in **Table 4.8** below based upon the IRC:52.

Table 4.8 Desirable Road Land Width (m) for Hill Roads as per IRC:52

Sl. No.	Road Classification	Open Areas		Built-up Area	
		Normal	Exceptional	Normal	Exceptional
1	National and State Highways (Double Lane)	24	18	20	18
2	Major District Roads	18	15	15	12
3	Other District Roads	15	12	12	9
4	Village roads	9	9	9	9

4.10.2 Standards given in the above Tables are for ideal conditions. Where such space is not available, the minimum space standards shall be followed so as to accommodate the required widths of grade separators and elevated roads as per relevant IRC Codes.

4.11 Camber or Crossfall for Straight Sections

Camber/crossfall shall be provided as per relevant IRC codes.

Camber on straight section of Elevated Structures/Grade separators/Flyovers etc. shall be 2.5% for bituminous surfacing and 2.0% for cement concrete surfacing. Where Annual Rainfall is 1000mm or more, crossfall of 2.5% shall be provided. The two-lane bridge shall be provided with a crown in the middle and crossfall on either side of the crown. The crossfall shall be unidirectional for either side carriageway in straight reaches for multilane divided carriageways. For ROBs, the cross camber should be provided as per Railways' /RDSO standard details and requirements.

4.12 Super-elevation

Super-elevation shall be provided on horizontal curves in accordance with the relevant IRC Codes and Manuals.

4.12.1 The effect of super elevation on stresses in the various members of the structure shall be taken into account in the design.

4.12.2 Super-elevation shall be limited to 7 percent, if radius of curve is less than desirable minimum radius. It shall be limited to 5%, if radius is more than or equal to desirable minimum radius and also at sections where the structure passes through an urban section or falls on a major junction. However, on urban sections with frequent intersections, it may be limited to 4 percent.

On Hill roads, super elevation shall be limited to 7% in snow bound areas and 10% in areas not bound by snow in accordance with IRC:52.

Super elevation shall not be less than the specified crossfall and method of attainment of superelevation shall be as per relevant IRC codes.

4.12.3 The desirable minimum and absolute minimum radii of horizontal curves for various classes of terrains for roads other than expressways are given below **(Table 4.9)**:

Table 4.9 Minimum Radii of Horizontal Curves for Highways in Non-Urban Areas (IRC:SP:73/SP:84/SP:87)

Nature of Terrain	Desirable Minimum Radius	Absolute Minimum Radius
Plain and Rolling	400 m	250 m
Mountainous and Steep	150 m	75m

However, in urban areas minimum radii of horizontal curves are specified in IRC:86 and IRC: SP:128 which are reproduced below **(Table 4.10 & 4.11)**:

Table 4.10 Minimum Radii of Horizontal Curves in Urban Areas (Table 8.2, IRC:86)

S. No.	Design Speed (km/hr)	Minimum Radius (m)when Super Elevation is Limited to	
		7 Per cent	4 Per cent
1	20	15	20
2	30	30	40
3	40	60	70
4	50	90	105
5	60	130	150
6	70	175	200
7	80	230	265

Table 4.11 Minimum Radii of Horizontal Curves for Expressway
(Table 2.5, IRC:SP:99)

Design Speed (km/h)	120	100	80
Absolute Minimum Radius (m)	670	440	260
Desirable Minimum Radius (m)	1000	700	400

IRC:73 may be referred to for other types of roads and IRC:52 may be referred for hill roads respectively for adopting minimum radii of horizontal curves.

4.13 Gradient

The ruling and limiting gradients for highways are given below **(Table 4.12)**:

Table 4.12 Gradients on Highways
(IRC:SP:73/SP:84/SP:87)

Nature of Terrain	Ruling Gradient	Limiting Gradient
Plain and Rolling	2.5%	3.3%
Mountainous	5.0%	6.0%
Steep	6.0%	7.0%

For expressways, gradients to be adopted as per IRC:SP:99 are as follows **(Table 4.13)**.

Table 4.13 Gradient for Expressways
(Table 2.9, IRC:SP:99)

Terrain	Ruling Gradient	Limiting Gradient
Plain	2.5 percent	3 percent
Rolling	3 percent	4 percent

The gradients in the approaching viaducts or earth embankments shall usually be limited to as per the relevant provisions of IRC codes. Ruling gradients shall be adopted as far as possible. However, in situations where sufficient space or length is not available then the gradients may be locally increased to meet the requirement after judiciously considering the type of traffic using the facility. But in any case, gradient steeper than limiting gradient should be avoided.

Urban roads generally have intersections at frequent intervals and in view of this, a gradient of 4 percent should be considered the maximum as per IRC:86. Steeper gradients are permitted for structures in hill roads for which IRC:52 may be referred to. In special situation of road carrying a large volume of slow moving traffic, it will be desirable to adopt a flatter gradient of 2% as per IRC:73.

4.14 Vertical Alignment

If there is a change of gradient on the bridge deck, suitable vertical curve shall be introduced conforming to relevant IRC codes and manuals. The vertical alignment should provide for a smooth longitudinal profile. Grade changes should not be too frequent as to cause kinks and visual discontinuities in the profile. In this regard, reference shall be made to IRC:73 and IRC:SP:23 for design of vertical curves. For structures in Urban areas, vertical alignment shall

be designed in accordance with the provisions given in IRC:86. For structures on hill roads, relevant provisions of IRC:52 shall be followed for design of vertical profile.

The aspect of efficient drainage shall be kept into consideration while designing vertical profile as stipulated in IRC:SP:42 and IRC:SP:50.

4.15 Horizontal Alignment

In general, horizontal curves should consist of a circular portion flanked by spiral transitions at both ends. Design speed, super-elevation and coefficient of side friction affect the design of circular curves. Length of transition curves is determined on the basis of rate of change of centrifugal acceleration and super-elevation. For design of horizontal curves, IRC:73 and IRC:38 may be referred to. Properly designed transition curves shall be provided at both ends of the circular curve and recommended minimum length of transition curves shall be provided as given in the applicable IRC Codes/Guidelines/Manuals.

4.16 Widening of Carriageway on Curves

Wherever sharp horizontal curves are provided in elevated structure/grade separators, it is necessary to widen the carriageway as per relevant codes. On horizontal curves on highways with radius up to 300 m, width of two lane carriageway shall be increased by 0.9m for radius of curve 75-100 m and 0.6m for radius of curve 101-300m.IRC:73 may be referred to providing extra width for different radii and multi lane carriageway. For urban structures, extra width of carriageway shall be provided in accordance with IRC:86 and IRC:SP:128. For widening of pavement of structures on hill roads, reference may made to IRC:52.

The structures having entry and exit ramps or loops should be provided with adequate length of acceleration/deceleration/merging lanes to ensure free and safe flow of traffic and to avoid congestion near the mouth of such ramps or loops resulting in traffic jams.

4.17 Sight Distance

4.17.1 Adequate sight distance shall be provided at all points on the road in conformity with IRC standards as given in Tables below **(Table 4.14 (a) & 4.14 (b))**:

a) 2-Lane, 4-Lane and 6-Lane Highways

Table 4.14 (a) Sight Distances For 4-lane & 6-Lane Highways (As per IRC:SP:84 / SP:87)

Design Speed (km/hr)	Safe Stopping Site Distance (m)	Desirable Minimum Sight Distance (m)
100	180	360
80	130	260
60	90	180
40	45	90

On 2-lane roads, at least twice the safe stopping sight distance shall be available throughout. The attempt should, however, be made to provide overtaking sight distance as far as possible. The recommended sight distances for 2-lane road are given below:

Table 4.14 (b) Sight Distances For 2-Lane Highway (IRC: SP:73)

Speed (km/hr)	Minimum Sight Distance (m)	Overtaking Sight Distance (m)
100	360	640
80	240	470
60	180	340
40	90	165

b) Expressways

For Expressways, following sight distances shall be provided for design speed of 120 km/hr based on IRC:SP:99.

Safe Stopping Sight Distance=250 m

Desirable Minimum Sight Distance /Intermediate Sight Distance=500 m

c) Urban Areas

In Urban areas, safe stopping sight distances are given below **(Table 4.15)** as per IRC:86.

Table 4.15 Safe Stopping Sight Distance for Various Speeds (IRC 86, Table-7.1)

S. No.	Speed (km/h)	Safe Stopping Sight Distance (m)
1	20	20
2	30	30
3	40	45
4	50	60
5	60	80
6	70	105
7	80	120

On undivided roads, intermediate sight distance which is equal to twice the stopping distance shall be provided where vehicles are permitted to cross the centreline.

d) Hill Roads

For Hill roads, sight distances shall be considered as per IRC:52 which are reproduced below **(Table 4.16)**.

Table 4.16 Sight Distances for Hill Roads (IRC:52)

Speed (km/hr)	Stopping Sight Distance (m)	Intermediate Sight Distance (m)
20	20	40
25	25	50
30	30	60
35	40	80
40	45	90
50	60	120

4.17.2 Headlight sight distance at Valley Curves

On valley curves, the design must ensure that the roadway ahead is properly illuminated during night travel by vehicle headlights for a sufficient length which enables the vehicles to brake to a stop, if necessary. This is known as the headlight sight distance and is at least equal to the safe stopping distance. From safety considerations, valley curves should be designed to provide for this visibility. For designing valley curves, the following criteria should be followed to ensure the headlight sight distance:

i) height of headlight above the road surface is 0.75 m

ii) the useful beam of headlight is one degree upwards from the grade of the road; and

iii) the height of object is nil.

4.18 Lateral and Vertical Clearances

The minimum horizontal clearance shall be the clear width and the minimum vertical clearance, the clear height available for the passage of traffic.

4.18.1 Overall considerations

4.18.1.1 Conscious effort must be made to create a sense of freedom for the drivers traveling through the underpass. As far as possible, the underpass roadway should conform to the natural lines of the highway at the approaches as regards alignment, profile and cross-section. Road profile should not dip too sharply under the structure as that will produce a considerably enhanced sense of restriction when compared with a profile that proceeds smoothly through.

4.18.1.2 To promote a feeling of openness and unrestrained lateral clearance, structures with open-end spans are recommended. Where it becomes necessary to have structures with solid abutments, these abutments should be set as far back from the roadway edge as possible. Since such structures involve higher costs, these treatments may be reserved for higher categories of roads, especially with divided carriageways.

4.18.1.3 Since widening of an existing underpass at a later stage involves considerable construction and diversion problems it is recommended that the initial construction itself should take into consideration such future needs. This is particularly applicable to underpasses on important routes like National and State Highways.

4.18.2 The minimum horizontal and vertical clearances for single and multiple lane bridges and underpasses with vehicular traffic shall be given as per the provisions of IRC:5, IRC: SP:73/ SP:84/SP:87 for roads in urban and non-urban areas, IRC: SP:99 for Expressways and IRC:52 for Hill roads. The clearance requirements for Underpasses in accordance with IRC:SP:84 and IRC:SP:87 for 4-lane and 6-lane highways are shown below **(Table 4.17)**:

Table 4.17 Clearances at Underpasses for 4-lane and 6-lane highways (IRC:SP:84 and IRC:SP:87)

Type of Underpass	Vertical Clearance	Horizontal Clearance
i) Vehicular Underpass (VUP)	5.5 m	20 m
ii) Light Vehicular Underpass (LVUP)	4 m	12 m
iii) Smaller Vehicular Underpass (SVUP)	4 m	7 m

For two lane highway, lateral clearance for underpasses shall not be less than 12m as per IRC: SP:73 and vertical clearances shall be same as shown in **Table 4.17**. For Vertical and Lateral clearances requirement for the structures at underpasses reference may also be made to IRC:54.

4.18.3 For foot ways and cycle tracks, a minimum vertical clearance of 2.25 m shall be provided.

4.18.4 As per IRC:5, for a bridge constructed on a horizontal curve with super elevated road surface, the horizontal clearance shall be increased on the side of the inner kerb by an amount equal to 5 meters multiplied by the super-elevation. The minimum vertical clearance shall be measured in meters from the super elevated level of the roadway. Extra horizontal clearance required for the super-elevation will be over and above the increase in width required on a curve.

4.18.5 Reference may be made to Section 3.24 for additional requirements of clearances for VUPs and Flyovers in accordance with NHAI Policy Circular no. 10.1.26/2021 dated 11.01.2021.

4.19 Interchanges

Grade separated intersections or interchanges are designed to carry fast moving motorised traffic, to decongest an at-grade intersection or to segregate the conflicting movements of an intersection, thus improving its operational efficiency. Reference shall be made to IRC:SP:92 "Guidelines for the Design of Interchanges in Urban Areas" for types of interchanges, shape and pattern of interchange ramps, planning considerations, geometric design factors, design speed and other considerations to be provided for interchange design.

4.20 Road Over Bridges (ROBs)

ROB is a road bridge constructed across railway tracks and designed for IRC loading.

4.20.1 RDSO Guidelines for ROBs

Railway guidelines have to be followed for planning of Rail over bridges (ROBs) across the railway tracks and within the Railway boundaries.

Railway Board has issued instructions to adopt standard designs of ROB girders issued by RDSO and also non-standard ROB spans designed and adopted by various zonal Railways. Reference may be made to the "Compendium for Road Over Bridges (ROBs) on Indian Railways (Report BS-132)"issued by Research Designs and Standards Organisation (RDSO) and recommended by MORT&H, which gives guidelines for planning of ROBs and is basically a repository of available drawings, catalogued properly to easily find the best suitable girder for a specific use case and thus save time in preparing the fresh designs and detailed drawings.

4.20.2 Vertical clearances

Vertical clearance for ROBs shall be kept as per the requirements of the concerned railway authorities after confirmation from them of the governing rules for the same. This requirement usually varies with the type of services by that line and also on account of the needs of electrification of railways or dedicated freight lines etc.

4.20.3 Horizontal clearances

The horizontal clearances between abutments or piers shall also be determined as per Guidelines published by RDSO and in consultation with railway authorities.

If the crossing involves one single line, provision may have to be made for second or more lines, in future. All these requirements, including future electrification system shall be finalized in consultation with railway authorities.

4.21 High Tension Lines

Where the grade separators or other elevated structures are being crossed by High Tension lines, the requirements of vertical and horizontal clearances below such lines shall conform to IRC:32 and should also be found out in consultation with the concerned authorities and it should be provided for in the design. The vertical clearances are to be provided above the bridge deck as per Indian Electricity Rule 77 for various overhead electric power and telecommunication lines.As per this rule, for high voltage lines the clearance above ground shall not be less than 5.2 metres for 33 KV line plus 0.3 metre for every 33 KV or part thereof by which the voltage of the line exceeds 33 KV, provided that the minimum clearance above the bridge deck shall not be less than 5.5 metres in accordance with IRC:32.

4.22 Design of Pedestrian facilities- Subways and Foot over Bridges

These shall be designed as per the relevant provisions of IRC codes. The foot over, bridges may be designed for crowded footpath loading of 500 kg/m^2 as per IRC:6. The clearances shall be as per IRC:5 or as indicated in above clauses. The access and exit to and from the subway and foot over bridge should be planned so as not to encroach in any manner upon the foot paths alongside the road carriageway and not obstruct the free flow of pedestrian traffic.

5. ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

5.1 General

The main consideration while conceiving and planning of an infrastructure project is its sustainability without affecting/damaging the environment.

Sustainable development is the one that meets the needs of the present without compromising the ability of future generations to meet their own needs. The following requirements should be ensured to achieve the sustainable development.

- Bringing in new Technologies, Automation, Artificial Intelligence
- Introducing new Materials, GFRP, CFRP, Aluminium, Carbon Fibre Cables
- Minimising material consumption by better designs
- Automated shop fabrication in protected environment
- Ensuring minimum work on-site exposed to climate and weather in planning
- Lighter structures with associated dynamic issues to solve
- Prepare bridges for new traffic modes

The direct impacts from Grade Separators & Elevated Structures use may include creation of physical barriers to existing physical and social linkages, increased demand for motor fuels; increased air pollution, noise and road side litter, injury and death to animals and people during accidents, health risk and environmental damage from accidents involving hazardous materials in transit, and water pollution from spills or accumulated contaminants on the surfaces.

Many of these direct impacts on natural systems, historical and cultural resources and right-of-way land uses (i.e. property severance) can be avoided if their causes and effects are understood at planning stage and remedial measures/mitigating measures incorporated at design stage and their implementation monitored during construction and post-construction stages.

On the other hand, .an aesthetically planned, designed, developed and maintained Grade Separators & Elevated Structure is not only pleasing to the eye but it also adds to travelling comfort, enhances environmental quality and provides better safety in traffic operations. Therefore, while planning Grade Separators & Elevated Structures, various activities such as choice of location for access and exit points, wayside amenities, facilities etc.; selection of pleasing alignment which merges with surrounding topography and natural environment; provision of services and utilities, etc. should be given due consideration and incorporated in design.

As a safeguard against the adverse impacts on the environment, it is essential to carry out Initial Environmental Examination (IEE). Thereafter Environmental Impact Assessment (EIA) including Environmental Impact Statement (EIS), Possible Mitigation Measures and Environmental Management Plan (EMP), be prepared at different stages matching with significant impacts identified during IEE.

The basic aim of these guidelines is for study, examination, evaluation of environmental issues and preparation of Environmental Management Plan arising out of human activities on account of planning, design and implementation of Grade Separators & Elevated Structures. Grade

Separators & Elevated Structures which generally provides numerous direct and indirect benefits should also be environmentally sound so as to ensure sustainable development of the region.

These guidelines on environmental system and aesthetics will go a long way in planning, design and implementation of Grade Separators & Elevated Structures on sustainable basis under Indian conditions and have been provided under the following heads:

i) Objectives and Definitions;

ii) Scope (matching various project activities);

iii) Property Severance Effects;

iv) Procedure for Environmental Impact Assessment (EIA);

v) Preparation of Environmental Impact Statement (EIS);

vi) Environmental Management Plan (EMP);

vii) Approach to Data Collection, Investigations and Identification of Impacts;

viii) Measures for Mitigation of Adverse Impacts;

ix) Environmental Monitoring;

x) Aesthetics.

Similarly, social impact assessment should be made to minimise the impact of the Grade separator & elevated Structures project.

5.2 Environmental analysis

All environmental studies shall be got done by a qualified and experienced Environmental Expert.

A Preliminary environmental/screening of the Grade Separators & Elevated Structures may be carried out to determine the magnitude of actual and potential impact and ensure that environmental considerations are given adequate weightage in the selection and design of the Grade Separators & Elevated Structures. In **Table 5.1**, a chart for initial environmental examination (IEE) and suggested grading and protection measures have been indicated.

Table 5.1: Recommended Mitigating Measures and Suggested Gradings for initial Environmental Examination (IEE)

Action Affecting Environmental Resources and Values	Recommended Feasible Mitigating Measures	IEE Grading
a) Environmental Impacts Due to Project Location		
i) Disruption to hydrology	May be avoided through planning measures	D2
ii) Resettlement	Suitable compensation and resettlement planning require consideration	D1
iii) Environmental aesthetics degradation	Care shall be taken to avoid/ minimise effect	D2
iv) Inequitable locations for rural roads	Suitable connectors to be planned as part of project.	D3

v) Loss of terrestrial ecology including forests and wildlife	May be avoided through planning exercise or minimize the effect with mitigation measures	D2
vi) Loss of swamp ecology	May be avoided through planning exercise or minimize the effect with mitigation measures	D2
b) Impacts During Construction Phase		
i) Site runoff from cut and fill area	Suitable measures to be adopted during construction	D1
ii) Safety creation hazards	All safety measures may be incorporated in tender document	D1
iii) Slum creation hazards	Appropriate planning for housing of construction workers must be made and incorporated in tender document	D1
iv) Cultural differences hazards	Should preferably be avoided and public learning be made and considered	-
v) Escape of hazardous material	Strict monitoring the movement of hazardous material	D2
vi) Escape of air pollution (including dusts)	Suitable measures will be adopted to prevent/ minimize	D1
vii) Noise and vibrations	Effect shall be assessed and measures taken based on significance	D1
viii) Quarrying hazards (including use of explosives)	Appropriate planning operation of blasting and use of operating quarries	D3
ix) Disruption of utilities along route	Shifting of utilities shall be planned in advance and provision kept in the project	D1
x) Disruption of traffic along route	Judiciously planned to avoid / minimize disruption	
c) Impacts during Project Operation		
i) Noise disturbances	Shall not go up from present level Consider provision of suitable noise abatement measures	D1
ii) Vibration disturbances	Appropriate planning and post-construction monitoring may be made	
iii) Air pollution	Appropriate planning and post-construction monitoring may be made	D1
iv) Continuing erosion	Protective vegetation and other methods shall be adopted	D1
v) Runoff contamination	Appropriate planning and post-construction monitoring to take care	D2
vi) Spills of hazardous materials	Appropriate spills control program and post construction monitoring to take care	D2
vii) Escape of sanitary wastes	Appropriate planning/post - construction monitoring to be considered	D1

viii) Congestion at access / exit points	Appropriate planning/post-construction monitoring be made to reduce/ eliminate the effect	D2
ix) Inadequate maintenance	Post-construction monitoring is recommended	D3

Note:

D1 - Not significant; D2 - Small significant effect; D3 - Moderate significant effect;

Information should be collected on existing environmental conditions for IEE along the selected alignment to determine the need for further environmental assessments, design and management studies.

Positive and negative impacts of new Grade Separators & Elevated Structures shall be identified. Cost-effective measures shall be proposed to enhance the positive impacts and to avoid or mitigate the effect of negative impacts.

Where felt necessary, public consultation on positive and negative impacts with the affected groups or involved NGO's may be carried out. Specially mitigation measures for negative impacts and assuring measures for positive impacts shall be explained.

5.3 Environmental design

From the environmental analysis, all elements with potential for adverse impacts should be identified, for which steps can then be taken to avoid/mitigate through judicious design changes, for example, shifting the alignment to save trees. Adverse impacts, such as, soil erosion, flooding, loss of vegetation cover, etc. should be identified and appropriate mitigating measures, like, ground cover planting, installation of proper drainage system, etc. incorporated in design to reduce the impact. Cost effective proposals may also be included in the design proposal to suitably enhance the environmental quality along the alignment in a sustainable manner.

5.4 Environmental management action plan

An implementation schedule and supervision programme may be prepared for timely execution of environmental mitigation and design works and all efforts may be made to follow the same. The programme for monitoring environmental impacts during construction and operation should be developed.

For such large projects, the requirement for institutional strengthening and training facility for personnel to be deployed on environmental works should be specified.

Any further studies of environmental issues, which are required to be undertaken during project implementation, should be recommended.

5.5 Social Impact Assessment (SIA) and Resettlement and Rehabilitation action Plan (RAP)

A Social, Resettlement, and Rehabilitation Expert shall be deployed for study of Social Impact and Rehabilitation and resettlement action plan.

Whenever the project will entail acquisition of land, structures and other assets and cause displacement or loss of assets within the public right-of-way, the project should undertake a socio-

economic base-line study and prepare a Social Impact Assessment (SIA) and Rehabilitation & Resettlement Action Plan (RAP).

From the study of Social Impact of the Project, mitigation measures are required to be prepared which are acceptable to the society. One of the major social impact of Grade Separators and Elevated Roads is severance of properties, which should be minimised through planning and design process.

The RAP has three main objectives

i) To assess and bring out the impacts of land acquisition and assets for the project civil works on the people who own properties in the area to be acquired or live on the land to be acquired and/or derive their income from the land or own enterprises operating on the land to be acquired.

ii) To present the entitlement policy for compensation and assistance to persons affected by the project,

iii) To prepare an action plan for delivery of compensation and assistance outlined in the policy to the persons duly identified as entitled to such assistance.

The present policy of the Government is that the persons adversely affected by the project should receive benefits from it or at the least, they should not be worse off than before because of the project. Since acquisition of land and other assets may be unavoidable and an integral part of project design and implementation, undertaking a social impact assessment and preparing RAP shall also be included as a part of project design from the start and undertaken in close co-ordination with environmental analysis and environmental action plan. Also, as far as possible involuntary settlement may be avoided or at least minimized wherever possible, by exploring other alternative project designs.

In cases where displacement, loss of assets or other negative impacts on people are unavoidable, the 'project should assist the affected persons with means to improve their former living standards, income-earning capacities, production levels or at least maintain the previous standards of living.

Since no civil work can be undertaken on any stretch before land acquisition and payment of compensation as per RAP, it is essential that planning and implementation of civil works may be coordinated with RAP. Preparation of RAP requires a thorough understanding of the local people, and the social, economic and cultural factors influencing their lives. It is essential that detailed base-line studies are conducted with a participatory approach through consultation with potentially affected persons and other stake holders in the area, the local NOOs, Municipal Authorities, etc. and a mutually satisfactory solution is achieved.

Reports of all Environmental and Social studies must be kept as a permanent record for future reference.

6. AESTHETICS

6.1 Structures should be designed and constructed to have a pleasing appearance. Reference may be made to Clause 112 Aesthetics of IRC:5 for guidelines to be followed for planning and design of grade separators and elevated structures.

6.2 The visual appeal of the structure can be attributed to its form, texture, colors, detailing and site context. For aesthetics to be successful it must be considered as an integral part of the design. Every part of the structure has a role to play both structurally and aesthetically in its totality. Aesthetics of the bridge must be considered both in the general form at the time of conceptual planning as well as in specific form (parts and details) at the design stage considering their participation in the development of whole concept.

6.3 Conceptual Stage:

At conceptual planning stage of a Grade Separator or Elevated Road, the following points shall be given due consideration in addition to guidelines given in Clause 112 of IRC:5.

6.3.1 Structures should reflect order and rhythm as cumulative effect of all the elements including pier shape, their spacing, proportion of deck with respect to span, external appearance, lighting poles, sign posts, railings and crash barriers as illustrated in **Fig. 6.1**

No Order and Rhythm between various elements

Re-arrange various elements to bring Order and Rhythm between them

Fig. 6.1 Order and Rhythm Illustrated

6.3.2 External appearance of grade separators and elevated structures should be designed so that they are in harmony with the local landscape, heritage, and local architecture to maintain the aesthetics of the surroundings.

6.3.3 Abstract form of the structure should be such that it should stand out and is viewed as an independent object.

6.4 Structural Elements at Design Stage:

At design stage, in addition to guidelines given in Clause 112 of IRC:5, the following points shall be given due consideration while designing the various elements of the bridge:

6.4.1 Deck Soffit with Utility Services: If the deck soffit is unsymmetrical or the structure is carrying some utility service, consideration should be given to hiding the utility service by extending the parapet soffit below the deck soffit.

6.4.2 Deck Profile: Variation in depth of superstructure is governed by structural considerations. However, sudden changes in depth and projecting cross beams should be

avoided and instead gradual flow lines with smooth profile should be provided as shown in **Fig. 6.2** below.

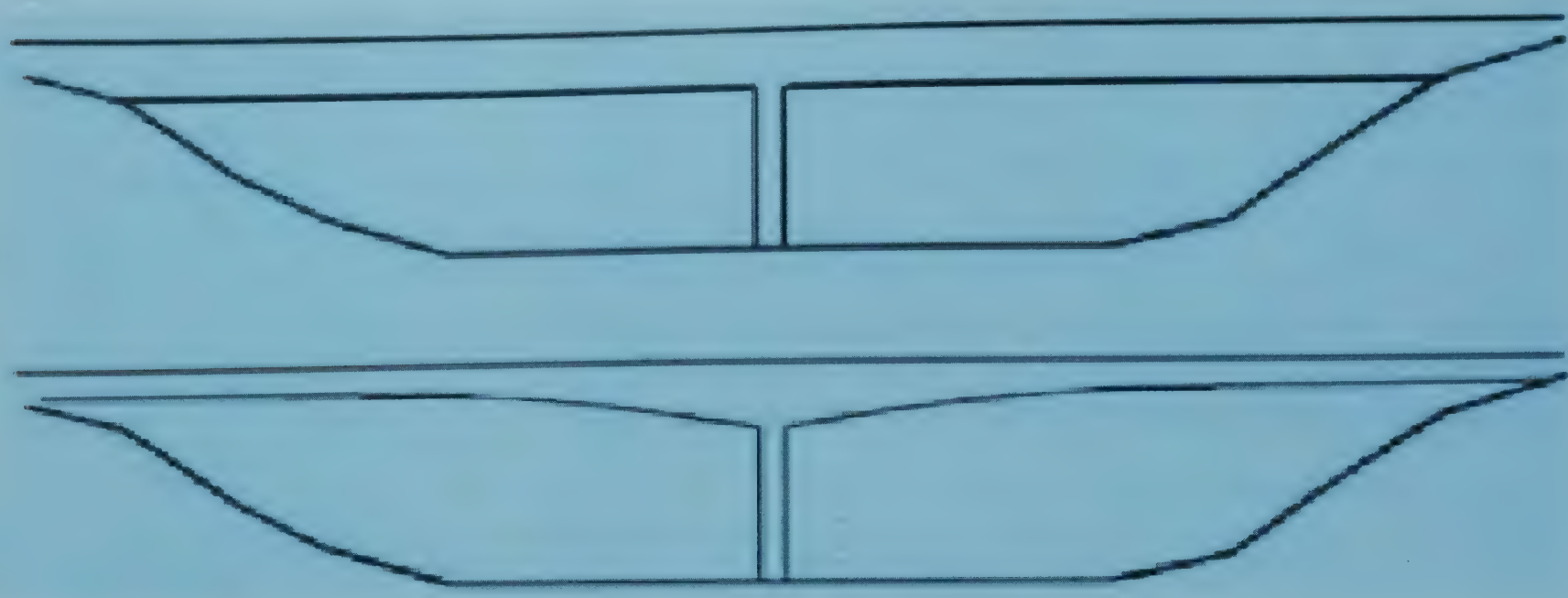

Fig. 6.2 Smooth and gradual change in soffit profile

6.4.3 Deck cross section: The cross-sectional shape of the deck should be provided to achieve slender structure, continuity of lines, harmonious appearance with substructure and effect of light, shade and texture as illustrated in **Fig. 6.3** below:

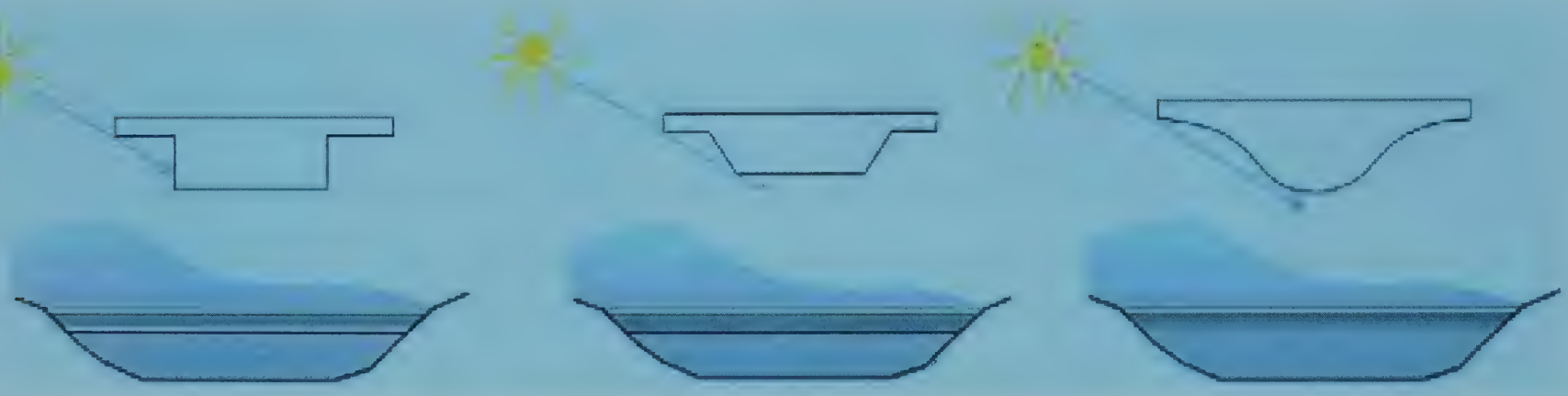
A right-angled connection can catch the light and a double line may be visible. Maximizing the overhang will increase the shadow.
An angled connection will minimize this effect.
A curved soffit will provide a gradation of tone and minimize a sharp line at the base of the beam.

Fig 6.3 Cross-sectional shape of Deck

6.4.4 Pier caps: Pier caps transfer the load from the deck to the pier and their dimensions are influenced by functional and structural considerations. The shape and size of the pier-cap should not dominate the view of the structure but blend with the superstructure above and substructure below to achieve an overall pleasing appearance as shown in examples below (**Fig. 6.4**). Integral type structure without pier caps may be considered wherever feasible.

Fig 6.4 Examples of pier caps blending with superstructure and pier below

6.4.5 Seismic restrainer blocks: Seismic restrainers should be located in such way so that they do not provide visually adverse aesthetic view and preferably should be either hidden or should look less dominant.

6.4.6 Crash barriers and Noise Barriers: Concrete crash barriers and noise barriers can make the superstructure depth appear to be deeper than its actual depth. Visual slenderness ratio, which is affected by solid crash barrier and opaque noise barriers, shall be considered while deciding the pier spacing. However, it should be considered that heavy shadow from the deck and curved soffits can reduce the apparent (visual) depth of the superstructure.

6.4.7 Pier cross section: Pier shapes with only two lines of symmetry (e.g. rectangles or ellipses) and transverse to the centerline of the deck are preferable to squares and circles as they present the thinnest edge to the side view. Elliptical shapes have the additional feature of providing a softer graduated reflection of light when seen in elevation.

6.4.8 Pile caps: Pile caps should not project out and should be buried below the ground.

6.4.9 Abutments: Dimensions of abutments should be so proportioned so that they make the abutment look slender and pleasing. As far as possible, return or wing walls should merge with the abutment structure either integral or with expansion joint with the abutment structure.

6.4.10 Drainage Arrangement : Drainage arrangement from the deck should be well planned so that they are not protruding from pier/abutment. Care should be taken to conceal the same within concrete subject to maintenance requirements.. Similarly water from drainage pipes must be led to designated drains to avoid spillage on the ground.

6.5 Detailing and Maintenance

6.5.1 There are important aesthetic considerations/effects in the detailing of components of the structure:

6.5.2 The detailing of the members like drip course, expansion joints, drainage systems etc. should be done so as to minimize the potential of staining.

6.5.3 Access for inspection and maintenance should be considered early in the design phase and should not adversely affect the aesthetics.

6.5.4 Painting of external visible pier and superstructure surfaces may be considered for beautification of the overall structure. Use of anti-carbonation paint is advised for improving the visual appearance and durability.

6.5.5 For a pleasing experience by the road user over the flyover, the railings, crash barriers, roadside kerb stones/blocks should be in line and level as per the road profile. The profile of expansion joints should also fit in the profile of the road to avoid bumps and noise under moving tyres. The median where provided should have grass, seasonal flowers, and decorative lights. During the life of structure, damaged railings, crash barriers, wearing course, expansion joints, and roadside kerbs need to be immediately repaired to keep them in service for the intended use.

6.5.6 Interchanges have plenty of open space between loops and ramps which can be beautified by landscaping and installing water fountains and statues wherever feasible.

6.5.7 The space below flyovers and viaduct should be beautified and entry should be restricted to avoid encroachments.

6.5.8 Wherever side drains are provided, these should be kept clean and maintained regularly. In urban areas, these are generally covered and due care should be given to achieve the smooth visual profile and finishes for a pleasing appearance rather than looking an eyesore.

7. STRUCTURAL DESIGN ASPECTS FOR ELEVATED STRUCTURES

Elevated Structures include flyovers, viaducts and elevated roads. The structural scheme, span arrangement and the type of structure shall generally be finalised early in the design process, which is at the conceptual design phase of the project. In order to develop an optimal solution, all relevant issues must be considered at the project forefront and a range of feasible alternatives will need to be examined before finalising the structural scheme. The optimum structural solution is influenced by several factors and shall be evolved after taking into considerations the following aspects:

7.1. Span length over the existing road or rail tracks, generally known as obligatory span, has to be chosen carefully considering the existing roadway, number of rail tracks, and their future widening due to increase in traffic. It is preferable to add one span on either side of obligatory span for providing U-turn if service roads are provided and also to accommodate any future widening of the lower carriageways.

7.2. The approach ramp may be provided either as solid fill ramp or a viaduct. In urban areas, it is preferable to provide a few viaduct spans for better visibility across the ramp. In built-up sections viaduct spans shall be provided in the approaches of the structure. However, embankment/RE wall/Retaining wall may be provided up to height as per guidelines. For this purpose, the height shall be measured from existing road level/service road level.

7.3. The type of superstructure should be chosen keeping in mind the ease of construction at the site without interrupting the existing traffic flow. Precast construction of superstructure is preferable for ease of construction and faster completion of the project. However, cast-in-situ spans may be provided in open remote areas if the length of structure is small. Indicative span ranges for different type of superstructure are given in IRC:SP:54. Aesthetics must be kept in view while deciding the span arrangement..

7.4. In precast concrete construction, the choice of type of superstructure depends upon the time available for construction, deck width, length of the structure, local site conditions and sub-soil strata. However, the economics of a particular structural system depends on project length, scheduled completion time, cost of casting yard, moulds, launching and erection of such spans.

7.5. For structural design reference shall be made to the relevant IRC Codes.

7.6. Where large obligatory spans, more than 50 m, are warranted such as over multiple rail tracks and multilane highways, either of the following types of superstructures may be provided.

- Box girder
- Balanced cantilever spans
- Steel Truss Bridge
- Arch/Bow string Arch bridge
- Extradosed bridge
- Cable Stayed bridge

Balanced Cantilever spans in PSC require large depth of superstructure which raises the formation road level (FRL) with an increase in length and cost of approaches. A through type steel truss, Steel Arch bridge and Extradosed bridge require less depth of the decking and are preferred.

7.7 Continuous spans or integral bridges should be preferred to minimise the number of expansion joints & bearings, improve the riding quality and minimise the maintenance cost. Continuity may be provided either through structural continuity or deck slab continuity. Spacing between successive expansion joints should be preferably in the range of 90 m to 100 m minimum wherever feasible. Suitable types of expansion joints and bearings need to be provided depending on the movements at the joint location. In certain situations, sharp curves may have to be provided for which stability, structural design, bearing arrangement and expansion joints require special attention.

7.8 For wide decks (greater than 12m), single cell box girders with/without struts or multi cell box girder may be adopted. Wide decks with large transverse spans may have to be transversally prestressed. Such decks are generally constructed as PSC precast segmental superstructure and dead weights are minimised for ease of handling, erection and launching.

7.9 Continuous/integral bridges, Arch bridges and Extradosed bridges and other complex structures require use of a proper and well recognised design software capable of their modelling, service & construction stage analysis, structural design including long term effects and deflections.

7.10 Superstructure supported on a single pier as shown in **Fig. 7.1** is preferred especially in built up areas where there are severe space constraints. Piers can be accommodated in central verge and space underneath the superstructure can be utilised for accommodating surface level traffic. Portal frames may have to be provided to support superstructure in certain situations where road underneath has to pass below the deck and piers cannot be provided in the middle of the road.

7.11 Use of cementitious additives/admixtures and high-performance concrete is to be encouraged from consideration of durability, sustainability and to make the structure look slim with pleasing appearance.

Fig. 7.1 Typical Example of Superstructure Supported on a Single Pier

8. UNDERGROUND STRUCTURES

8.1 General

Underground structure is a generic name given to structure which is built into the ground by various techniques such as, by cut and cover construction by using bottom-up or top-down techniques, by using box pushing techniques, by bored tunnel method or by NATM. The underground structures covered in this guideline are vehicular underpasses, pedestrian underpasses, underpasses for non-motorised traffic (for crossing of cattle/animals), RUB's. Underpasses are increasingly being used in urban areas, as a grade separator at the intersections. As compared to elevated flyovers, underpasses offer following advantages:

a) Reduced environmental impact to the built environment.

b) Reduced vertical clearance requirements for slow moving traffic (e,g. cyclists and pedestrians, cattle) can lead to reduced length of ramps on either side and minimise grade differentials.

Underpasses typically comprise of a ramp-down and ramp-up, open-to-sky portion and a closed-to-sky portion at the intersection. The structural scheme and the type of structure will depend upon several factors such as.

i) Traffic demand

ii) Sub-surface conditions

iii) Geometry of the intersection and surrounding

iv) Underground and over ground utilities

v) Oil characteristics

vi Design and construction of underground structures in cut and cover technique embraces a wide and varied range of structures and involves complex structural engineering challenges.

Important considerations for design and construction for Underpasses are listed below:

a) stability of the structure against uplift due to buoyancy as a whole and also during construction.

b) water tightness of the structure to prevent seepage.

c) drainage of the subway.

d) construction aspects such as excavation, traffic diversion scheme etc.

e) existing services and future provision, if required.

f) ventilation consideration.

g) lighting and other utilities.

8.2 Form and Layout of Underpasses

There are no conventional methods which will give general solution to creation of grade separators at major intersections. Site constraints/space restrictions at site demands site-specific planning and design and use of high technology input in the construction methodology. It requires a good

planning after considering the various options to overcome any constraint. Various possible forms for Underpasses are given below in **Table 8.1**.

8.3 Methods to prevent Floatation of Underpass

The structure should be checked for overall stability against uplift. Due to high water table, there is buoyancy force which causes upward water pressure and leads to floatation of underpasses. There are various techniques to prevent the floatation as given below.

a) Soil/Rock Anchors provided below the base slab

b) Filling inside Underpass with high density material (such as Iron Ore)

c) Tension Piles provided below the base slab

Artesian condition, if any, should be studied for finalisation of the foundation location and type of foundation.

8.4 Construction Methods

Details of the excavation procedure should be decided at the design stage itself based upon the nature of soil, economy, suitability of the construction scheme, traffic diversion and existing utilities etc. Various techniques for construction of underground structures are as follows:

a) Cut and Cover with open excavation, shoring with bottom-up construction or shoring with top down construction

b) Box Pushing

c) Tunnelling with TBM / NATM

Special precautions need to be taken during excavation considering the safety of existing structures, pedestrian, and vehicular movement and dewatering method.

Table 8.1 : Various Possible Type & Techniques of Underpass Construction

	Type of Wall	Usage	Sketch	Remarks / Comments
1.	Cut and Cover Underpass structure with open foundation	Most common form in situation where open excavation is feasible.	Refer **Fig. 8.1**	This method of construction can pose some challenge due to constriction of space in urban situations or in situation where water table is high. Where sloping of excavated portion is not feasible, suitable shoring may be required to stabilize the excavation.
2.	Diaphragm Walls 'with' or 'without' supplementary strutting system	Common in urban situation where open excavation is not possible from considerations of traffic and constricted space and / or where water table is high	Refer **Fig. 8.2**	Diaphragm wall permits construction and excavation very close to existing buildings or other movement-sensitive installations. Diaphragm wall requires minimum working space and this has substantial advantage over conventional open cut and cover techniques. However, the construction method suffers from the disadvantages like noise, vibrations and use of bentonite slurry, which has environmental issues.

3. Piled Walls with Contiguous Piles or Secant Piles	More economical than diaphragm walls in small to medium scale excavations due to reduction in cost and time of site operations.	Refer Fig. 8.3	Merits of column piles are less noise or vibration than produced by the installation of soldier piles or sheet piles. Column piles have greater stiffness than soldier piles or steel sheet piles. They avoid excessive bulk excavation and help to control ground movements. There are two distinct bored pile wall options in current use: Contiguous wall and Secant wall.
4. Soldier Piles with timber / steel lagging or sheet piles or secant piles	Used often as a temporary wall for shallow/Moderately deep excavation.	Refer Fig. 8.4	Soldier pile walls are temporary walls formed by constructing soldier piles at regular intervals followed by excavating in small stages and installing lagging followed by backfilling and compacting the void space behind the lagging. Soldier pile and lagging walls are the most inexpensive systems compared to other retaining walls. It is also very easy and fast to construct.

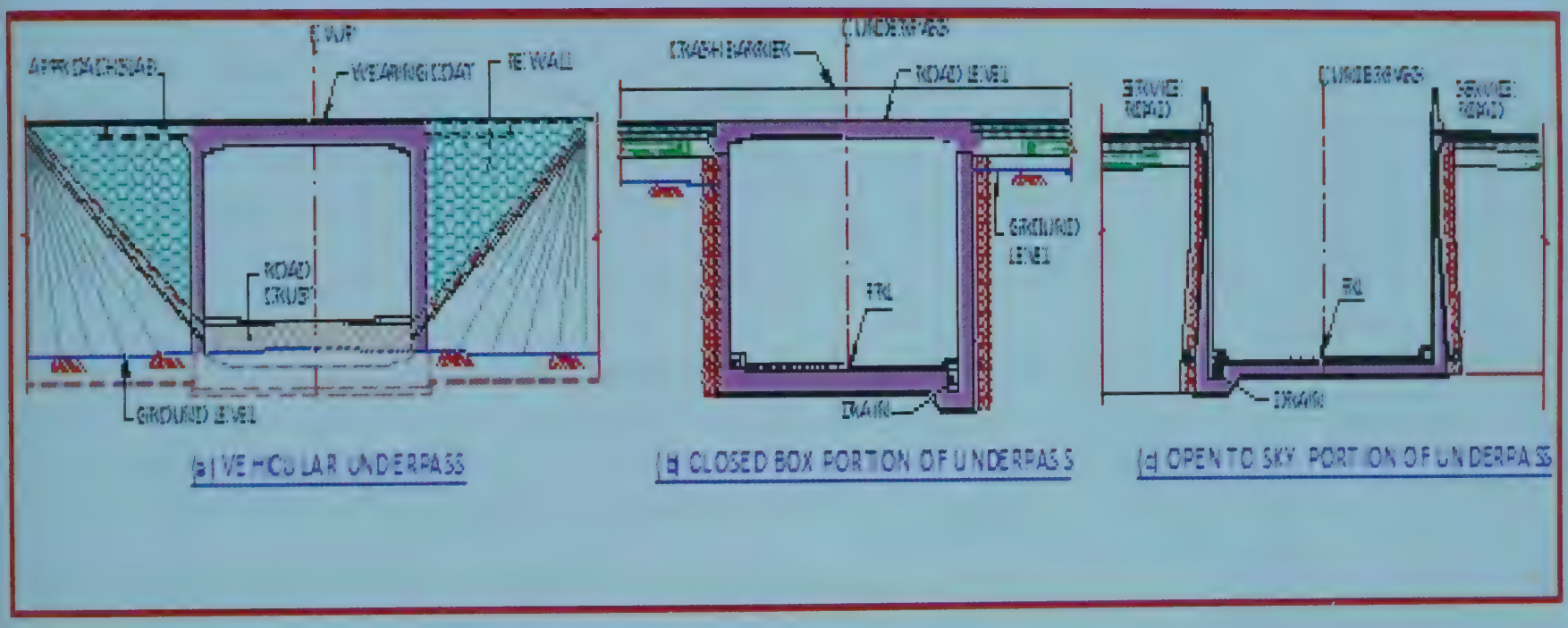

Fig. 8.1 Underpass with open Excavation

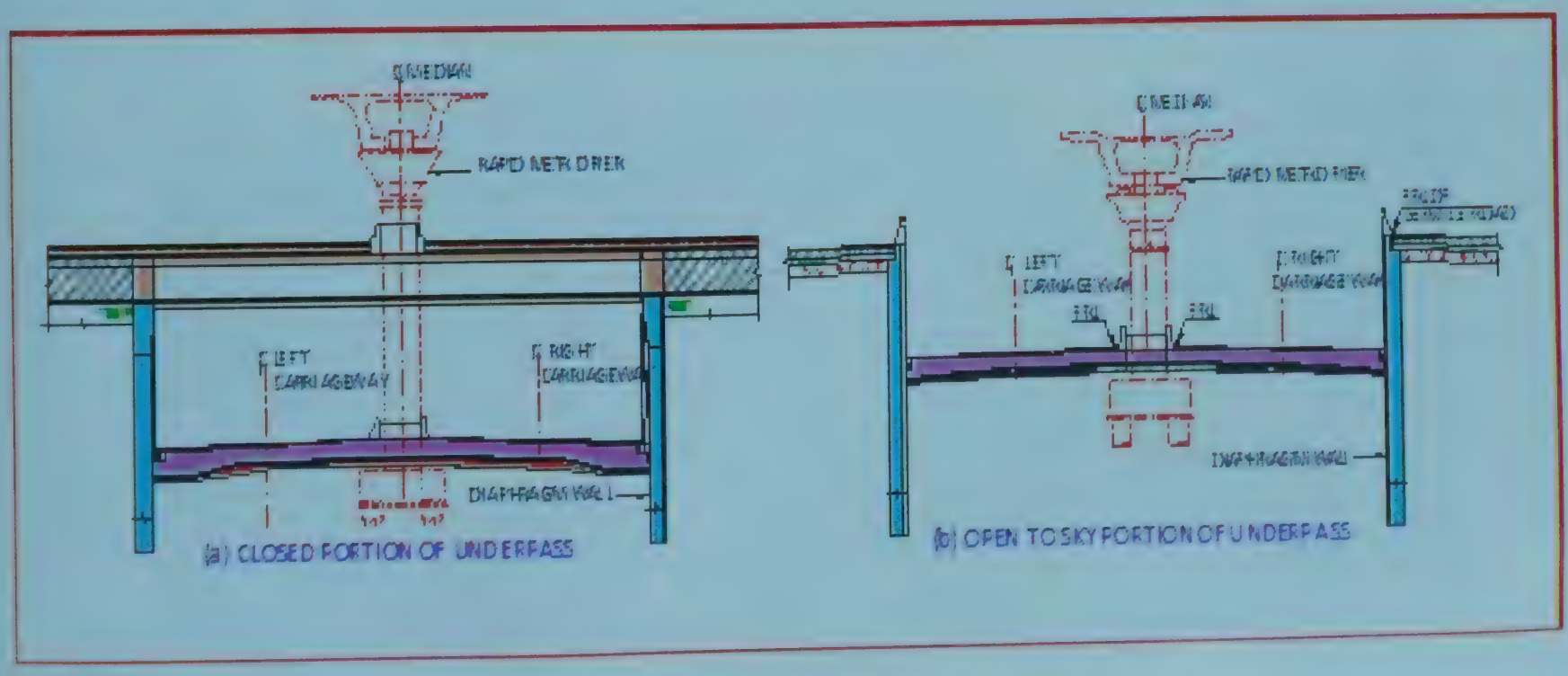

Fig. 8.2 Underpass with Diaphragm Wall

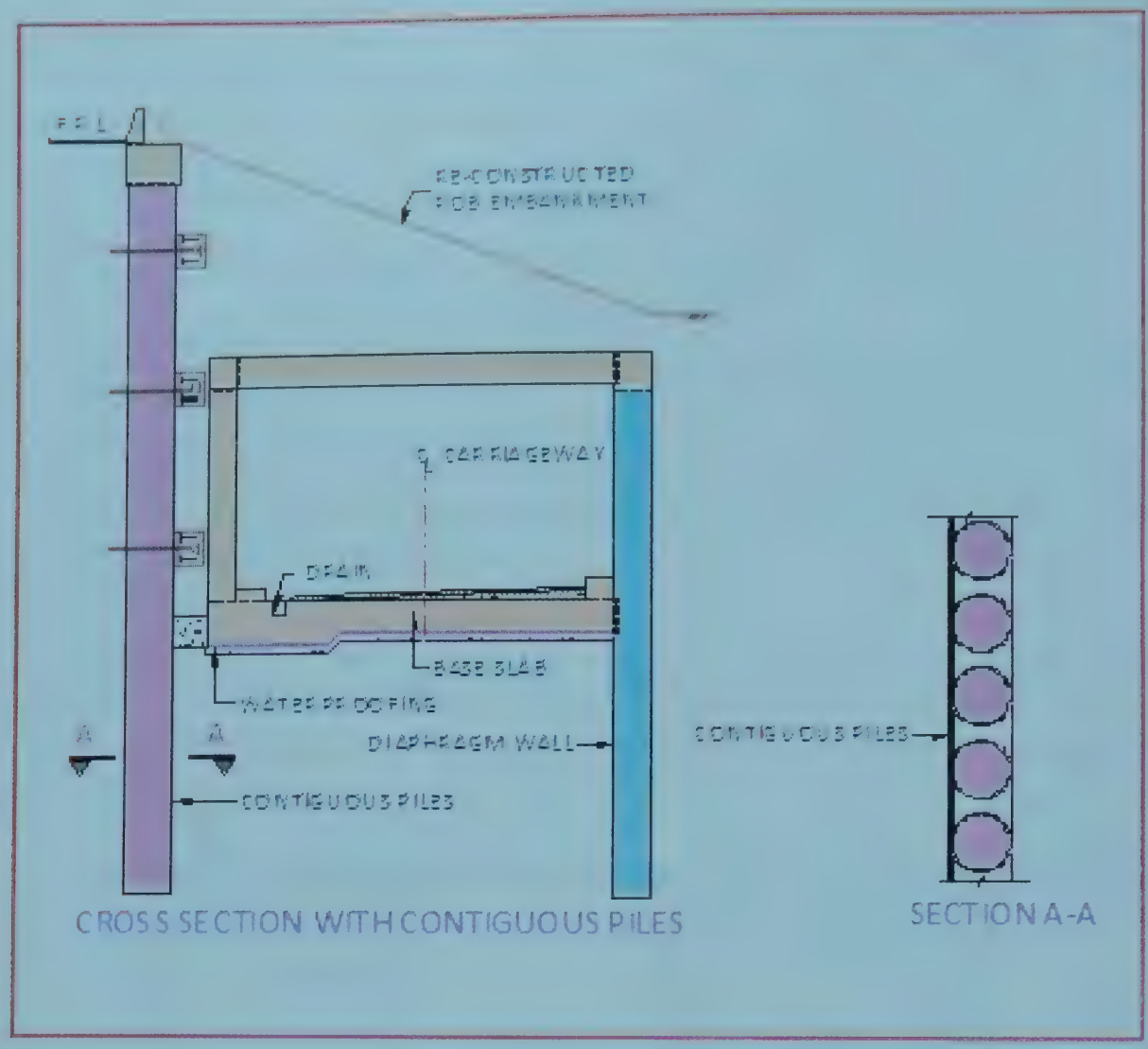

Fig 8.3 Underpass Using Contiguous Pile

Fig 8.4 Soldier Piles with timber lagging

8.5 Dewatering of Underpass during construction

In situations where water table is high and above the level of excavation, there will be need to lower the water table locally by dewatering to ensure dry condition during excavation and concreting. Dewatering by unsuitable methods can under some conditions cause damage to adjacent properties, and result in failures. The geology, ground water conditions, and type of excavation all influence the selection of dewatering technology. The most common methods for dewatering include sumps, wells and well points. A number of other dewatering techniques are available including ground freezing and electro osmosis. However, such techniques are used only for particularly difficult dewatering applications.

8.6 Ventilation of Underpasses

An underpass is generally termed as tunnel when the roof covered length of road exceeds 90 metres as per National Fire Protection Association (NFPA, 2001). For tunnels of short length, the natural air flow through the tunnel driven by the movement of vehicles is normally adequate to manage in-tunnel air quality, and forced ventilation is not required. For longer tunnels forced ventilation in the form of fans may be required at times to ensure that air flow rates are sufficient to maintain in-tunnel air quality to required levels. In such cases, simulation analysis including one dimensional and three dimensional (CFD) analysis needs to be performed for different performance scenarios, which shall include normal, congested and incident (fire emergency) operations.

For the normal operation, the main objective is to control the in-tunnel pollution levels under normal operation scenario. Designated vehicles shall be considered for emissions. The acceptable limits of Carbon Monoxide (CO) and particulate matter (PM) shall be taken from relevant national codes and/or specialist literature.

Congested operation or an Incident operation results from any obstacle in the tunnel, which will lead to vehicles moving either at a very slow speed or are in stopped condition. The emissions will be higher in this case as compared to the normal conditions. The same emission rates and limits for denser traffic shall be considered in this scenario.

An emergency or fire occurring on any vehicle or other fire, vehicles upstream of fire will be disabled in the tunnel. Evacuation may be required in this scenario. Relevant standard of NFPA (National Fire Protection Association) shall be applicable for the design of ventilation for fire life safety. The ventilation system shall be designed to extract smoke to ensure that the motorists struck downstream are not affected. The air velocity inside the tunnel shall be maintained above the critical velocity to avoid back layering of smoke.

8.7 Design & Detailing Issues

Unless otherwise stated below, the design and detailing of underpasses shall conform to the provisions of IRC codes and standards. Design is construction driven and design shall ensure safety at each and every stage of construction and during service.

a) **Seismic:** Treatment for earthquake resistant design for underpasses shall be different as compared to over ground structure. In general, seismic design loads for underground structures are characterized in terms of the deformations and strains imposed on the structure by the surrounding ground, often due to the interaction between the two. In contrast, surface

structures are designed for the inertial forces caused by ground accelerations which shall be designed as per IRC:SP:114.

b) **Design water level for Buoyancy Assessment:** The design water table for evaluation of floating of underpass or for liquefaction potential shall be assumed to be the highest water table that can exist at the site over several weeks in a year. Weep holes in retaining walls of underpasses should be avoided due to aesthetic reasons since water flow from weep holes spoils the inward surfaces of the retaining walls leading to an ugly appearance. The walls can be designed for full hydrostatic pressure in addition to the normal lateral earth pressure. Alternatively, a longitudinal perforated pipe can be provided behind the walls with outlets towards the inner side at a close spacing.

c) **Waterproofing of Underpass:** Underpasses are highly susceptible to water leakage and subsequent structural damage which reduces serviceability and durability of the structure. To ensure, water tightness, the structure may be designed as uncracked or with limited crack widths. Due to the soil and groundwater conditions, it is critical that the structure be protected from groundwater infiltration and a suitable site specific waterproofing system be selected for the structure.

The protection of an underground structure can be performed using a positive side (exterior) or negative (interior) waterproofing system. In general, the preferred system is a positive side waterproofing system that protects the structure from all types of attack while providing a tight waterproof membrane. Negative systems are typically used in rehabilitation systems where the exterior of the structure is not accessible. There are numerous waterproofing systems available in the market place:

a) Liquid systems towelled or mopped

b) Panel systems

c) Sheet membranes

d) Epoxy systems

e) Sprayed systems

f) Hybrid systems

The selection of a grouting program for any project must be site specific and performed as a complete system and be compatible with the chosen waterproofing system. The installation of any grouting program must have qualified contractor and experienced fulltime inspection personnel to ensure a quality product.

8.8 Drainage of Underpass

For underpasses, the possibility of designing the storm water drainage based on gravity flow should be targeted. In case the surrounding levels do not permit gravity based system of drainage, suitable automatic system with sensors for pumping and disposal of water shall be provided. The approach ramps to underpass may also be covered with transparent roofs to avoid rainwater entering into the ramps.

8.9 Illumination of Underpasses:

Clause 110 of IRC:5 may be referred for guidelines on illumination of underpasses.

9. APPROACHES

9.1 Approaches are the ramps which connect the ground level road to the abutment of a grade separator and elevated structure. These can be provided either as solid fill earthen ramps or viaduct or a combination of the both. At the end of the approach ramp joining the abutment, an approach slab is provided with its one end resting on dirt wall and the remaining length resting on the compacted earth fill.

9.2 Layout of the approaches to a grade separator depends upon its type. In case of an underpass the less important road runs at grade. The minor road may cross the main highway through grade separation or may first meet the service road. In case of subway the minor road can be taken under the main road without disturbing the latter. In case of an overpass the less important road may flyover the main highway. Where flyover is to be provided its alignment may cross one or more roads at intervals. If for allowing uninterrupted flow of traffic on main road an interchange becomes necessary, a number of forms are available to choose from. Depending upon operational characteristics, configuration of interchanges can be a trumpet, diamond, cloverleaf, rotary and directional. Trumpet interchange is adaptable to T or Y intersections. Diamond interchange is a 4 leg design and is particularly adaptable for major minor highway intersections.

Cloverleaf interchange provides continuous movement to all interchanging traffic and is suited for crossing of two major roads of equal importance. Rotary interchange is particularly useful where a number of roads intersect at the interchange. Cloverleaf and rotary interchange thus require considerable land.

All of the interchanges are connected to ground by ramps configuration of which differs from one type of interchange to the other. The point where the ramp meets the ground is called ramp terminal. The point from where traffic takes off is called entry terminal and where it touches down the ground is called exit terminal. The configuration of entry and exit terminal varies from one type of interchange to other. Whereas the entrance terminal should provide for sufficient length of acceleration lane to enable a driver to increase his speed from that on turning ramp roadway to that of operation speed of the highway as also to provide manoeuvring space so that the driver can watch and take advantage of an opening in the adjacent stream of through traffic, the exit terminal should be provided with sufficient length of deceleration lane to enable vehicles leaving the highway at high speeds to reduce their speeds to negotiate the turning curve on the exit ramp. Both the acceleration lane and deceleration lanes can be taper type and parallel type. The nose separating the through lane from the turning lane is offset from the edge of the through lane by 2 m to enable an errant vehicle to return.

The specific form or type of grade separator thus depends upon the importance of intersecting roads, traffic on each road, physical condition of site such as topography, available right of way, land use and developments alongside the intersecting roads, expected volumes of through and turning traffic.

9.3 Geometry of the approaches to the grade separator finally selected would depend upon the layout plan prepared for the grade separator as per the No. of lanes of traffic going up or down and requirement of left or right turning traffic. For segregating the traffic approaching or exiting the grade separator, suitable exit & entry ramps along with a weaving length are

necessary for the design of which IRC:92 and other relevant IRC codes & Manuals may be followed.

9.4 Drainage

The problem frequently faced at the entry or exit point of the grade separator is drainage of water coming down the ramps during rainy season. The problem has to be addressed by means of suitably designed catch water drains provided at exit/entry terminal and draining the water into the drainage system of the area. In addition, adequate number of down take pipes should be provided for efficient drainage of the entire approach ramp. Reference may be made to Clause 9.5 to 9.10 of IRC:SP:42 for drainage guidelines to be followed for the approaches. If approaches are constructed as reinforced soil ramps, reference may be made to clause 4.4.10.1 of IRC:SP:42 for providing adequate drainage.

9.5 Road Signs and Signals and illumination

One of the important points in the design of approaches is the location of road signs and Signals and illumination which should include the following:

- Furnish advance notice of the approach to the grade separator.
- Provide Directional signs to drivers into appropriate lanes well in advance of diverging or merging movements.
- Specify Identification of routes and their directions
- Specify Distances to destinations
- Provide any other information beneficial to driver
- Provide adequate illumination for drivers

Location of these sign boards and their heights at which to be displayed is very important. Size and lettering of signs is also important. The signs should be lighted and be reflective type and to be provided as per relevant IRC codes. Reference may have to be made to IRC:5, IRC:67 and relevant MORT&H Specifications and applicable Manuals for detailed guidelines & specifications.

10. CONSTRUCTION METHODS & CONSTRUCTABILITY ISSUES

10.1 Construction methods to be adopted at site are to be envisaged at the design stage itself, taking into consideration site conditions and constraints and the structures need to be designed accordingly. Basic aim is to choose the most suitable type of construction and minimise chances of modification of construction technology midway during execution. Further, the methods adopted should entail speedy construction, minimum inconvenience to existing traffic, and minimum noise and air pollution and safety. Accordingly, construction methods such as, open excavation or piling for foundations, column or wall type substructure, cast-in-situ, precast, or segmental construction for superstructure and push launching of box structure for underpasses and RUBs can be appropriately considered. For approach ramps, solid fill reinforced soil walls are preferred for ease of construction and economy.

10.2 The execution of works at the construction site must comply with the requirements given in latest MORT&H Specifications, various relevant IRC codes and the minimum requirements as stated in this standard. Some of the construction stage issues which require utmost attention are:

a) Planning to ensure minimum on-site Works

b) Effective barricading all around the construction activity area during construction

c) Efficient waste disposal at site

d) Measures for noise reduction

e) Road Maintenance during construction

f) Environment friendly construction

g) Efficient Traffic Management (i.e. Traffic Diversion, Close coordination with Traffic Police, Temporary signages, Provision of Traffic Guards and Blinkers, Adequate lighting during night)

10.3 Efficient construction management involves use of appropriate technology that suits the construction site needs, efficient planning and monitoring which ensures quality and speed of work, good contract documentation and experienced project management team who shall take charge of the organization of the works and ensure the correct and safe use of the equipment and machinery, the required quality of materials, the execution of structure and its safe use upto the delivery of the works.

10.4 For long viaducts and elevated structures, segmental construction may be suitable which requires establishing a casting yard close to the site, construction of precast segments and their stacking, transportation to the site, erection and launching of the segments. All the activities have to be carefully planned to avoid any mishap during the construction. Wide decks supported on single piers are common since it saves the space below deck. However, casting and erecting such heavy segments has its own challenges and logistic problems. Generally, spine beam box segments are precast in a casting yard, transported and erected at site and assembled to complete the span. After prestressing the spine beam, cantilever wings which are cast separately are installed and fixed to the spine beam. However, in some cases, cantilever wings and spine beam are cast in one operation. **Fig. 10.1** to **Fig. 10.4** show casting, transportation and erection

of such wide deck segments. Complete construction schedule up to operation stage shall be finalised , based on actual pilot construction sequence.

10.5 Apart from segmental concrete box girder construction, there are other types of superstructure constructions such as precast concrete or steel girders with cast-in-place deck slab, full span pre-casting and spliced girder system. Reference may be made to IRC:SP:65, IRC:SP:71 and IRC:SP:104 for their construction related guidelines.

Fig. 10.1 Construction of a typical Wide Deck Segment in the casting yard

Fig. 10.2 A Typical Wide Deck Segment being transported

Fig. 10.3 Erection and Launching of Wide Deck Segments

Fig. 10.4 Completed View of Viaduct with Wide Deck Segments

11. DRAINAGE

11.1 Effective drainage shall be provided both longitudinally and transversely in a grade separator and elevated structures. The transverse drainage shall be secured by means of suitable camber in the roadway surface. Longitudinal drainage shall be secured by means of longitudinal gradient in the road. The run-off shall be drained by using drainage spouts, inlets, or other suitable means of sufficient size and numbers. In Urban areas, generally drainage spouts may be connected to runner pipe of suitable diameter (minimum 100 mm) and taken down by down take pipes at pier and abutment locations.

11.2 Drainage plans and hydrological report for the Grade Separator should be prepared by the Consultant as per latest relevant IRC codes and guidelines and shall be submitted for review of and acceptance by the authorities.

11.3 Unless stated otherwise in any IRC codes, standards or contract document, drainage from the structure shall be diverted away from the Right-of-Way at all times. Drainage spouts from structure deck shall not be permitted to discharge water onto the track or roadway areas underneath at any time. The drainage spouts in a span may be connected to running pipe along the span to carry the runoff to a down-take pipe at pier location which discharges into the drainage system at lower surface. These horizontal and down-take pipes are placed inside the recesses in the structures for easy maintenance and aesthetic considerations. If drainage of deck uses downspouts in the piers, then they shall be connected to the storm drain system or allowed to drain into drainage ditches away from Right-of Way.

11.4 Lateral clearances shall provide sufficient space for construction of the required standard ditches parallel to the standard roadbed section. The size of the ditches should vary depending upon the flow and terrain and should be designed accordingly.

11.5 Drainage fixtures and down spouts shall be of rigid, corrosion resistant material not less than 100 mm in internal diameter and shall be provided with suitable cleanout fixtures. These shall be covered for good visual appearance.

11.6 The arrangement of floor drains shall be such as to prevent the splashing discharge of drainage water against any portion of the structure. Overhanging portions of concrete deck shall be provided with drip moulds.

11.7 Catch water drains are necessary at the end of the viaduct portion so that water coming from span does not over saturate and affect the earthen embankment. Similar catch water drains shall be provided at the end of the gradient so that water coming from flyover is properly let out to the nearest drain.

11.8 An integrated drainage plan for the water coming from the deck of the structures, local catchment area of the project and all other sources shall be prepared by the Consultant as per available IRC codes and guidelines and shall be submitted for review of and acceptance by the authorities. It shall be ensured that no water falls on any/ other surface of the structures, or remain standing or flowing over the level roads.

11.9 Following IRC Codes may be followed for guidelines on providing efficient drainage system for grade separators and elevated structures.

a) Clause 109.2 of IRC:5-2015

b) Clause 9.5 to 9.10 and Clause 4.4.10.1 of IRC:SP:42

c) IRC:SP:50

11.10 For underground structures, adequate drainage of ramps and cross roads shall be ensured as described in Para 8.8 of Chapter 8 Underground Structures. For VUPs and PUPs over the cross roads, a longitudinal gradient of at least 0.3% should be provided for efficient drainage below the underpass so that there is no stagnation of water.

12. ILLUMINATION

Recommendations relating to lighting of Grade Separated Structures, ROBs, RUBs, flyovers etc are detailed in IRC: 5 Code of Practice for Road Bridges, Section-1 and IS:1944 Part 5 dealing with Illumination for Grade separated junctions, bridges and elevated roads and the same should be followed. In addition, following aspects should also be taken care while planning illumination in such structures.

12.1 Illumination plan shall be considered during initial planning and the expert should be involved in designing the Illumination system. The top and underside of the grade separated structures and interchange area at the ground level upto 50 m beyond the point from centre on all legs of interchange/crossing both at top and bottom shall be provided with lighting.

The arrangement of the masts/poles i.e. its height and spacing, lanterns, fixtures should be such as to achieve the minimum values of Luminance as per relevant IRC Codes IRC:5, Highway Manuals IRC:SP:73, IRC:SP:84, IRC:SP:87,IRC:SP:128(Urban Roads Manual) and IRC: SP:99 (Expressway Manual). In addition, codes and specifications listed at the end of this chapter may be referred to.

12.2 Electric poles on superstructure of elevated structures/grade separators shall be mounted preferably outside the crash barrier or in the central median if provided. One typical arrangement for supporting the electrical pole on crash barrier is shown in the **Fig. 12.1** below:

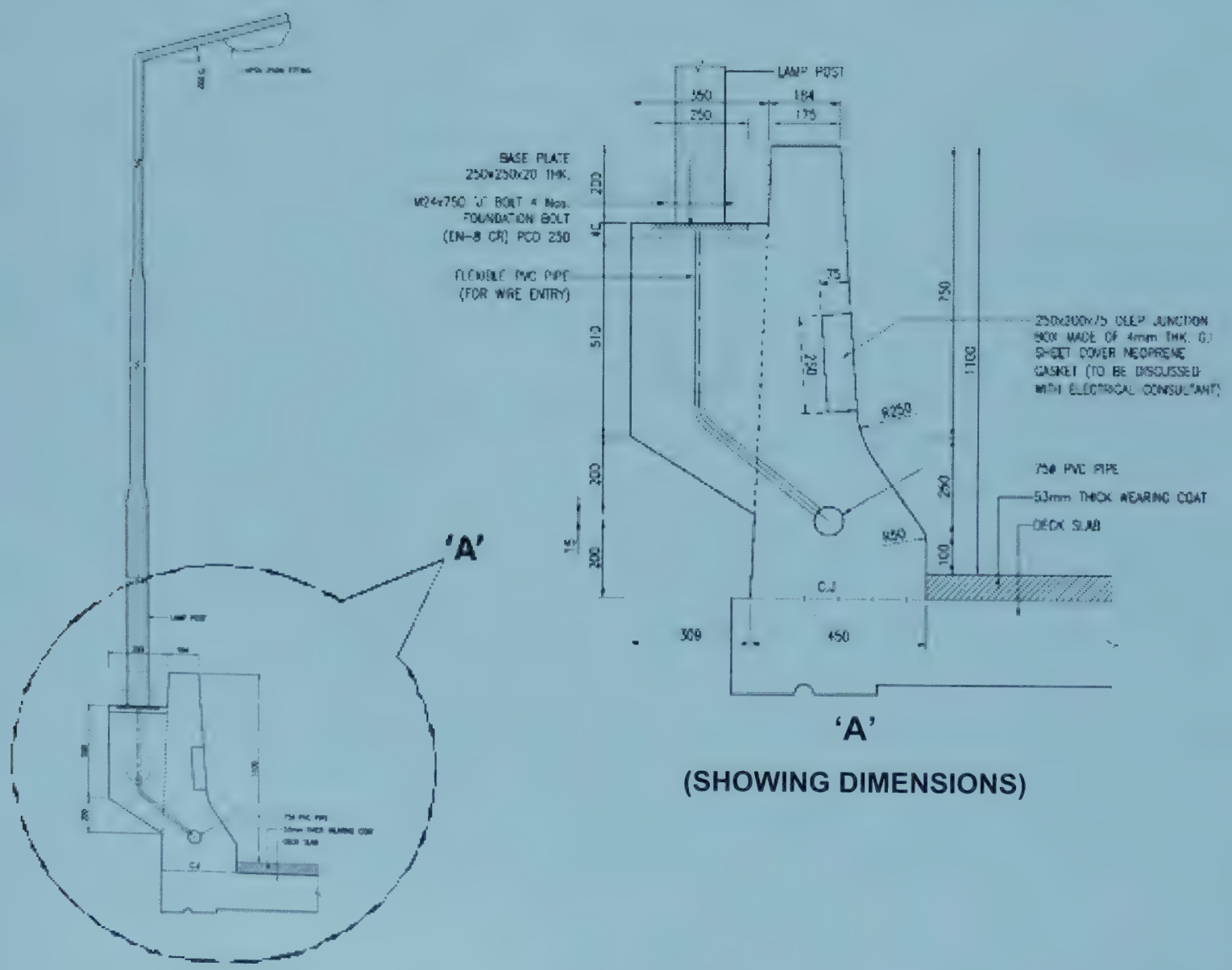

Fig. 12.1 Electric Pole supported on Bracket outside Crash Barrier

While deciding the illumination plan, considerations shall be given to energy efficiency, environmental pollution, aesthetic and economical aspects. The selection of lighting system and the layout should add to the overall aesthetic of the bridge. Wherever feasible solar lighting may be provided.

12.3 Design and Specifications of High Masts

High masts are to be generally designed as per the guidelines given in the Technical Report No. 7 of the Association of Public Lighting Engineers, U.K. as published in 1976. The masts should be designed for withstanding a 3 second gust of a specified wind speed as assessed from IS:875 (Part 3) depending on its location, defined ground roughness category and specified class of structure for a return period of 25 years. The luminaries should be integrated type i.e. Single housing should accommodate the luminaries (Flood lights) and its control unit.

The mast shall be manufactured from high tensile steel plate, cut and folded to form continuously tapered polygonal profile. Height of mast varies from 12.5 m to 30 m. The 30 m mast shall comprise of three suitable lengths before installation. The number of horizontal press fits should in any case not exceed three. The three sections should be fitted together on site in a manner that does not require any BSEN 10025 welding. Rather, one unit should be fitted telescopically into another with sufficient anchorage length to ensure that no transverse welding of the joints are needed. Transverse welds will not be allowed in the body of the mast.

Steel conforming to BS:1461(1999) or equivalent IS shall be used for the construction of the mast and after all welding processes are completed, the mast shall be hot dip galvanized to BS:1461 (1999) or equivalent ISS. The base flange shall be manufactured from steel plate free from laminations. The base shaft should penetrate the full depth of base plate and should be welded both above and below using a semi automatic MIC shielded arc process.

Gussets shall be located between each hole position, for additional strength.

Base compartment shall consist of an access opening to the base compartment should be an aperture of dimensions 240 mm x 740 mm approximately and should be reinforced to maintain the strength of the mast. Computer calculations for stresses and deflections should take into account the reinforcement of the access opening. The base of the left out door should be located on a substantial leg and secured at the top by means of recessed/socket head screw.

Base board shall be provided for mounting electrical and control equipment and should have minimum dimension of 315 x 395 mm. Earthling Terminal shall have M12 hexagonal head bolt complete with saddle bracket located on the left of the access opening of the mast shall be used as earthling terminal. The head frame, designed to be a capping unit of the mast, shall be welded steel construction and hot dip galvanized after assembly.

The lantern carriage shall be of the sheet steel construction and shall be hot dip galvanized after assembly. The carriage shall be in the form of a ring split on one diameter, enabling it to be assembled or removed from the shaft after erection. The outside base of the ring shall be provided with spigots or supporting brackets welded to it, depending on the form of lighting required. 4 sets of double rollers on the inside of the ring which engage with the slides on the mast head shall be provided, to ensure that when the carriage is fully home there is no movement between the carriage and the head frame. Additionally, a PVC buffer section shall be provided for protection of the mast during lowering the carriage.

A cast aluminium junction box located on the lantern carriage and housing connections to the lantern shall be provided. The junction box shall also have provision for connection of the flexible mast electric cable. The junction box shall be of casketed construction to ensure complete protection against weather.

A wiring duct shall be provided which should carry electrical wiring from the junction box to the lanterns. Each mast shall be provided with flexible multi-core cable. The conductor core shall be insulated with Ethylene propylene rubber and the complete cable core shall be sheathed in heavy duty polychloroprene.

An electrical disconnect shall be provided at the base of the mast comprising a socket with coupling ring and threaded plug including one set of 3 MCB SP and 1MCB for NL for complete disconnection of electric supply. It shall be possible that for lowering the lantern carriage, the electrical cable is disconnected at the base, so that it is free to travel within the mast.

The double drum winch shall have a safe working load of 330 kg for each drum at operating speed of 380 rpm. The winch shall be capable of handling total loads of up to 660 kg. Two cast iron worm reduction gear boxes shall be provided, which shall be filled with lubricant in the factory and should require no further attention at site. The gears shall have a reduction ratio of 50: 1 and provision shall be made for both manual as well as electric power drive.

The drum shall be fabricated from steel. To ensure correct rope stacking, a minimum one full layer of rope shall remain on the drums after the lantern carriage has been lowered to its lowest position. The double drum which shall use an arrangement of two independent ropes and each rope shall have one end attached to the lantern carriage and the other and clamped to the winch drum.

The control arrangement shall allow two sets of gears and their drums to be rotated simultaneously from a single driven shaft for normal operating duty of raising and lowering. Additionally, a separate manual function shall permit the lower drum to be rotated independently for leveling the lantern carriage. Additional safety features shall include disc brake on both gear shafts and automatic gravity latches which separately lock each drive shaft. Each winch shall be numbered and separately tested.

All wire ropes shall be of stainless steel and having a tensile strength, of 165 kg/mm^2. The rope shall have a construction of 7/19 on a PVC core to combine corrosion resistance with flexibility. The rope of 6 mm diameter shall provide a 330 kg of safe working load at a safety factor of over five. The central core of wire rope shall also be stainless steel. No intermediate joints in the wire ropes are acceptable.

The external electric driven power tool shall be single speed (1.2 meters per minute) single phase, hand operated motor. The power too shall be completed with very robust remote-control switch such that the tool can be operated from safe distance of five meters.

The maintenance cage shall be designed to accommodate two men together with any maintenance equipment and shall comply where relevant, with the constructional (lifting operations) regulations, 1961. The cradle shall be capable of raising or lowering by the mast winch and wire ropes. The entire maintenance cradle shall be hot dipped galvanized after fabrication. A maintenance manual shall be finalized during installation of the mast and the floodlights to ensure regular inspection and proper maintenance.

12.4 Reference Codes and Specifications for Lighting

The design and specifications of electrical system shall comply with the following standards and codes.

1. IS:1944(PT5):1981: Code of Practice for lighting of public thorough fare : Part 5 Lighting for Grade separated junctions, bridges and elevated roads.
2. IS:1944(PT1&2): 1970 Code of Practice for lighting of public thorough fare: Part 1 & 2 for main and secondary roads (Group A and B).
3. IS:3043: Code of Practice for Earthing.
4. The Electricity Act 2003 for electrical works.
5. National Electrical Code.
6. Indian Electricity Rules,1956(Latest Revision)
7. CPWD –External and Internal Specifications
8. IRC: SP:73, IRC: SP:84 and IRC:SP:87 (Manuals for Highways)
9. IRC: SP:128 (Urban Roads Manual)
10. IRC:SP:99 Manual of Specifications & Standards for Expressways.

13. ROAD SAFETY APPURTENANCES

Appropriate plan for road safety appurtenances like markings, signage, delineation, and signals (where necessary) shall be prepared and integrated with the overall bridge and interchange planning. These should cover the Flyovers, Grade separators and their approaches, Interchanges to facilitate smooth and safe movement / operation of traffic without creating any confusion among users and also to avoid the possibilities of serious accidents or damage to the structure or any of its components in the event of accidents. Provisions should be made in the structures for supporting of signals, signage and delineators.

13.1 Road Markings

13.1.1 The road marking symbols, patterns, sizes, colour and legends shall be adopted in accordance with Code of Practice for Road Marking, IRC:35.

13.1.2 Where the number of lanes on the Grade Separator and on approaches is different a transition taper should be given. The excess carriageway width in the transition zone should be appropriately chevron marked to ensure that it does not form part of the travelled way. There should be a corresponding sign as well to indicate narrowing or widening of carriageway.

13.1.3 Hazard markers and / or crash cushions shall be provided at beginning of median or crash barrier clearly indicating start of a Grade Separator, flyover, service road or loop emerging from main carriageway.

13.1.4 Chevron Markings / Painted Islands shall be provided at all exits to slip roads from main highway before a bridge / flyover or vice versa.

13.1.5 The road markings should be reflective type for clear vision during nights.

13.2 Signals

13.2.1 Signals near or on the structures shall be provided as per specific requirement of the any particular project conforming to the requirements of IRC: 93.

13.2.2 Signals can be either Electrically Operated or Solar powered with energy efficient lighting system.

13.2.3 Flashing Beacons shall be provided at beginning of median or crash barrier clearly indicating start of a Grade Separator/flyover, Service Road or loop emerging from main carriageway. Provisions of cables for power supply to any such signal shall be considered in addition to the regular illumination.

13.3 Road Signs

13.3.1 All multi-lane Flyovers, interchanges and grade separated structures shall be provided with adequate and proper signage at suitable locations in a prominent and suitable manner well in advance giving adequate response time to the users to read and take action. These signs should conform to the provision specified in IRC: 67 and only retro-reflective signs shall be provided.

13.3.2 The adequacy of the signage is more important for multilane or loop interchanges/ ROB where traffic flows uninterruptedly in different directions and hence direction signage are to be used There should be a bold and prominent sign board just before every entry or exit point in addition to repeat sign boards to regulate the traffic to the much before the exit and the entry.

13.3.3 Similarly, the direction signs on approaches should be provided if there is a junction close to the end to guide the descending traffic on the grade separator to choose lane accordingly.

13.3.4 The location of barrier kerbs and supporting system of the sign boards should be designed and planned along with the project and detail of the scheme shown in drawings.

13.3.5 Support system for signs required on structure decks shall preferably be placed behind rigid type crash barriers. The sign supports shall be structurally safe and properly anchored to the deck. The structure shall be designed to withstand all such loads.

13.3.6 Wherever signs are to be illuminated by electric powers, necessary arrangements shall be made for cable ducts.

13.4 Delineators and Road Studs

Delineators (also referred to as guideposts) shall be provided as per safety requirements in accordance with IRC:79. These shall be installed along the side of the roadway in a series to indicate the alignment of the roadway. Delineators are particularly beneficial at locations where the alignment might be confusing or unexpected, such as at lane reduction, transitions and curves. These delineators should have reflective tapes/paints for night vision. In addition, Hazard Markers and Object Markers shall be provided in accordance with IRC: 67, IRC:79 and IRC:67. Road studs shall be provided to improve the visibility in night time and wet weather conditions.

13.5 List of Reference Codes and Specifications

Following IRC codes and specifications may be referred to for Road Safety Devices:

a) IRC:5-"Standard Specifications and Code of Practice for Road Bridges"-Section-1

b) IRC:35-"Code of Practice for Road Marking"

c) IRC:67-"Code of Practice for Road Signs"

d) IRC:79-"Recommended Practice for Road Delineators"

e) IRC:103-"Guidelines for Pedestrian Facilities"

f) IRC:119-"Guidelines for Traffic Safety Barriers"

g) Section 800 of MORT&H Specifications

h) IRC:SP:73,IRC:SP:84 and IRC:SP:87-2L/4L/6L Manuals of Specifications and Standards

14. SAFETY REQUIREMENTS

The construction industry in general and urban construction sector in particular shall be considered as a priority for structure's health and safety, due to the high number and rate of work-related fatalities and inherent risks associated with working in such an environment. "Each life is precious" Keeping this in mind, the safety aspects therefore shall be given utmost priority by all the stakeholders for any grade separated structures at all stages of execution and maintenance,

14.1 Safety Requirements to be considered in design

Requirements of safe design means the integration of control measures early in the design process to eliminate or, if this is not reasonably practicable, minimize risks to health and safety throughout the life of the urban grade separator structure being designed.

The safe design of a grade separated structure will always be part of a wider set of design objectives, including practicability, aesthetics, cost and functionality. These sometimes-competing objectives need to be balanced in a manner that does not compromise the health and safety of those who work on or general public who use the structure over its design life. The design should consider safe geometrics, turning radius, safe design speed, super-elevations, extra widths on curves and merging or exit lanes etc. as specified in various IRC codes and IRC:SP:88 "Manual on Road Safety Audit". Road side kerbs and railings/crash barriers should be properly designed and located. Grade Separators /Elevated structures should be properly illuminated for safety of users. Provisions for inspection and maintenance should be incorporated at design stage itself so as to ensure safety and durability of the structures during its design life.

Safe design begins at the concept development phase of a structure when making decisions about:

a) The design and its intended purpose

b) Appropriate materials to be used

c) Redundancy and robustness in bridge structure is desirable. Bridges should not be fracture critical.

d) Possible methods of construction, maintenance, operation, demolition or dismantling and disposal. Design should be construction friendly.

e) Provision for road/lane marking signs/strips, illumination level.

f) Provision for prevention of impact / collision of vehicles

g) Provision against glare from vehicles coming from the opposite side on the other carriageway.

h) Provision of arrangement for prevention of speeding vehicles from jumping over the divider/ median to the other carriageway.

i) Provision of physical stopping over-height vehicles from crossing the facility.

j) Legislation, codes of practice and standards that need to be considered and complied with.

In addition, Construction/Erection Effects shall be accounted for at detailed design stage itself to avoid any mishap during construction phase.The effects of erection as per actual loads based

on the construction programme shall be duly accounted for in the stage-by-stage analysis and design of permanent structures. In the case of bridges constructed using bridge deck erection equipment (BDEEs), the permanent bridge designer shall have a full understanding of the BDEE operation and the loads to be accounted for during construction. As construction/erection progresses, the structure shall be secured to support dead, construction/erection loads, and other loads anticipated to occur during the period of construction/erection.

14.2 Safety Requirements to be considered during Construction

Grade Separator and Flyover construction safety needs special attention due to proximity of the construction area to road crossing and intersections, involving high density of pedestrian and vehicular movement. These are potential traffic hazard zones. The measures for Safety of workers and public and traffic arrangements during execution shall in general comply with the requirements set forth in MORT&H Specifications and other relevant IRC guidelines.

All the formwork, staging, and temporary structures need to confirm to site conditions and shall be properly designed as per IRC:87 and approved by competent authority. The same shall be erected and maintained properly. The temporary works need continuous inspection for structural stability and avoiding any overloading at any place, at any stage. The workers moving in the area should have helmets and safety belts where required. Precast construction of superstructure requires special safety measures during lifting, transportation, erection & launching of heavy concrete segments. Stability and safe design of launching scheme has to be ensured by deploying skilled manpower and experienced designers. Poor quality of concrete in segments, their inadequate gluing and matching may lead to accidents during prestressing and launching.

Enough barricading should be done in a clean and systematic manner to enclose the work areas such that the traffic passing adjacent or in the vicinity of the site is safe and do not face any problems and the construction activities do not attract undue attention of the traffic and cause any disturbance to it. The entire construction corridor should be adequately lighted at night and enough warning/diversion/direction signs distinctly visible from distance during day and night, should be installed for safe working conditions and for facilitating the traffic.

All the equipment, machines and plants, erection, lifting and launching arrangements should be properly tested before use for performing the duties for which they would be used during construction.

Site office and the entire construction corridor should be properly planned and laid out for proper running of vehicles and all other activities to avoid any chances of accidents and site should be maintained neat and clean of waste materials, scraps or spilled oils, diesel or greasy or any inflammatory materials.

All measures should be taken to avoid or mitigate air, water and soil pollution so that there are no health or safety hazards.

People working on bridges and roadways are required to wear special colorful and reflective clothing, foot protection, eye and face protection and most importantly head protection. It makes workers visible to drivers in work zones, which helps prevent accidents before they happen.

The project site should have enough provisions of firefighting, disaster management and medical facilities to deal with any such situations satisfactorily.

Work zone safety audit should be conducted at bridge sites, which helps the project participants to enhance their understanding of the potential risks facing the work zone. Work zone safety audit can be used as proactive safety tool to improve work zone safety and mobility performance.

Traffic diversions and related documentation shall comply with provisions of IRC: SP-55 and IRC:67.

In addition, following safety precautions in design should be taken during the Constructior stage.

a) Structure should be stable at each construction/erection stage under all loads, including the temperature induced loads, wind or earthquake induced loads, as defined in the code. The support restraints during all construction stages shall be checked for stability. If needed, temporary restraint shall be proposed during construction phase.

b) Incidental loads for crane boom collision or any impact of construction equipment may be considered in design depending on the type of construction, precast erection/cast in-situ.

c) Threshold limits of actions and methodologies such as temporary locking arrangements to avoid accident or collapse of both temporary & permanent structure during cyclone/wind beyond design wind speed.

d) Erection and casting sequences/procedures along with assumed construction and bridge deck erection equipment loads/configurations etc. shall be clearly indicated in approved sequence of construction drawings.

14.3 Safety of Road Users during the service life of the Structure

Apart from regular maintenance of the structure as a whole, it has to be ensured that any potholes in the carriageway, damaged expansion joints, broken railings and crash barriers, vanished road markings and defaced/defective traffic signs are quickly repaired/replaced. Structural Health Monitoring should be implemented to monitor the health of bridge components and bridge as a whole. The structure should be inspected and maintained regularly as described in Chapter 15.

15. INSPECTION AND MAINTENANCE

15.1 Introduction

15.1.1 The grade separators are very important structures and need to be kept in traffic worthy condition at all times. It is necessary that all these structures are regularly inspected as per a pre-determined program or for specific requirements and maintained or repaired or rehabilitated at the earliest as may be demanded as per the result of these inspections.

15.1.2 The inspection and maintenance of grade separators can be done conforming to the relevant provisions of IRC:SP:35. Guidance may also be taken from IRC:SP:40 for detailed inspection of items requiring repairs and strengthening.

15.1.3 Durability and longevity of structures, especially for urban grade separators is affected because of increasing industrialization giving rise to increased level of pollution and toxicity in the environment which render these structures liable to premature deterioration.

As such, a suitable inspection and maintenance program need to be evolved and put in place to take timely remedial measures and rehabilitate the structure before the situation worsens so that the structure can serve for their designed life. For this purpose, an appropriate bridge inspection record consisting of data gathered and recorded while checking the condition of various parts of the structure and following up the deterioration process from one inspection to another, needs to be created and properly maintained.

15.1.4 Some of the parts like bearings, expansion/contraction joints, drainage arrangements, etc. require special and frequent attention. Their malfunctioning affects the health of the structures leading to distress/deterioration which calls for regular and timely inspection. Arrangement for bearing replacement including jacking up locations etc. should be shown in the pier cap drawings as well as marked on the structure.

15.2 Access for Inspection

15.2.1 To facilitate inspection, suitable facilities should exist for the personnel to access the parts which are to be inspected for maintenance. Mobile inspection units like the one typical unit shown below (**Fig. 15.1**), can be deployed wherever feasible, or local arrangements suiting the requirements of inspections can be made.

15.2.2 A suitable access system provided as a part of the structure can be more helpful for carrying out regular inspection and maintenance. The design of a grade separator, therefore, should provide for facilities for detailed inspection of the structure.

15.2.3 Inspection platform around pier and abutment with railings and access ladders should be provided for this purpose where piers have large heights and pier caps are not easily accessible for inspection.

Fig 15.1 Typical Pictures of Mobile Inspection Units

15.2.4 Modern techniques including use of drones or instrumentation may also be used for carrying out inspection.

15.2.5 An opening in the diaphragms of box girders of size suitable for inspection inside the box should be provided. The size of opening should be such that men and equipment can be taken inside. Sometimes manholes are provided in the bottom slab of the box.

15.2.6 For long flyovers and continuous bridges, access vestibule at one end may be ideally suitable. Such a vestibule provides easy access to the inside of the box girder and even heavy equipment can be taken through this vestibule. This area can be used for housing bridge monitoring equipment. This also helps in relieving the earth pressure surcharge on abutment.

15.2.7 Expansion joints provided at the end of girders on the top of pier and abutment need regular inspection. A suitable space between the end faces of main beams or an inspection gallery around pier facilitates this inspection.

15.2.8 Leakages from the drainage spouts or down take pipes should be noticed and remedial measures taken immediately. Inspection of drainage spouts can be done from footpaths.

15.2.9 Deflection/Camber monitoring is an important aspect of inspection. Suitable platforms constructed to facilitate taking readings will be helpful in monitoring deflection/camber of the girders.

Some 100 mm square patches made even at regular longitudinal and transverse intervals (as reference locations on the carriageway) could be used for periodic collection of profile data. Such periodic deflection/profile monitoring of the superstructure enables taking appropriate corrective measures including resurfacing.

15.2.10 Where footpaths have not been provided, a walkway or gangway is helpful for inspection and maintenance personnel.

15.3 Drainage System

The drainage system should be carefully inspected before and during rainy season to ensure that its functioning remains effective and serviceable during the critical conditions. Any stagnation or collection of water over the deck, carriageway, valley curves or in surrounding lanes or areas should be noticed so that appropriate remedial measures be implemented.

15.4 Illumination System

The entire illumination system for the grade separator, signages and surrounding area need to be inspected frequently to check its functioning and effectiveness. The frequency of its failure at any point should be analysed and proper remedial measures be taken to ensure that sufficient illumination is available at all locations during night or darkness.

15.5 Maintenance Manual

A maintenance manual should be prepared for each of the grade separators which shall include any special or specific maintenance requirements because of the design philosophy or site requirements etc. The maintenance of the structure should accordingly be ensured.

(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)

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